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# DEVELOPMENT DOCUMENT FOR EFFLUENT LIMITATIONS GUIDELINES AND NEW SOURCE PERFORMANCE STANDARDS FOR THE UNBLEACHED KRAFT AND SEMICHEMICAL PULP SEGMENT OF THE PULP, PAPER, AND PAPERBOARD MILLS POINT SOURCE CATEGORY

Environmental Protection Agency

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Effluent limitations guidelines are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available" and the "Best Available Technology Economically Achievable" which must be achieved by existing point sources by July 1, 1977 and July 1, 1983, respectively. The "Standards of Performance for New Sources" set forth a degree of effluent reduction which is achievable through the application of the best available demonstrated control technology processes, operating methods or other alternatives.

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# EFFLUENT LIMITATIONS GUIDELINES
and
# NEW SOURCE PERFORMANCE STANDARDS
for the
# UNBLEACHED KRAFT AND SEMICHEMICAL PULP SEGMENT OF THE PULP, PAPER AND PAPERBOARD MILLS POINT SOURCE CATEGORY

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# Abstract

This document presents the findings of a study of the unbleached kraft, semi-chemical and paperboard segment of the pulp, paper, and paperboard industry for the purpose of developing effluent limitations for existing sources and standards of performance for new sources to implement Sections 304 (b) and 306 of the Federal Water Pollution Control Act Amendments of 1972 (The "Act"). The first phase of the study is limited to unbleached kraft mills, neutral sulfite semi-chemical (NSSC) mills, unbleached kraft-NSCC (cross recovery) mills, and paperboard from waste paper mills.

Effluent limitations are set forth for the degree of effluent reduction attainable through the application of the "Best Practicable Control Technology Currently Available," and the "Best Available Technology Economically Achievable," which must be achieved by existing point sources by July 1, 1977, and July 1, 1983, respectively. "Standards of Performance for New Sources" set forth the degree of effluent reduction which is achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives.

The identified technology for July 1, 1977, is good in-plant waste water management followed by preliminary screening, primary sedimentation, and biological treatment. The 1977 limitations can be met by mills utilizing only secondary treatment, but a combination of in-plant controls and biological treatment may be more cost effective.

The identified technology for July 1, 1983, is in-plant waste water controls and secondary treatment. The identified in-plant controls may require some major changes in existing processes and design modifications to existing equipment. In addition, filtration with possibly chemical addition and coagulation is identified for TSS reduction. Physical-chemical treatment for color removal is identified for four of the five subcategories.

The identified technology for new source performance standards is in-plant waste water controls and secondary treatment. Physical-chemical treatment for color removal is identified for two subcategories. The identified in-plant controls and external treatment systems are available for implementation as they have all been demonstrated at mills within the subcategories under study.

Supportive data and rationale for development of the effluent limitations and standards of performance are contained in this report.

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## SECTION I

## CONCLUSIONS

For the purpose of establishing effluent limitations and standards of performance, the unbleached kraft, neutral sulfite, semi-chemical and paperboard segments of the pulp, paper and paperboard manufacturing industry have been subcategorized as follows:

Unbleached Kraft
Neutral Sulfite Semi-Chemical (NSSC) - Sodium Base
NSSC - Ammonia Base
Unbleached Kraft - NSSC (Cross-Recovery)
Paperboard from Waste Paper

Within each identified subcategory, factors such as age, size of plant, process employed, climate, and waste treatability confirm and substantiate this subcategorization for the purpose of establishing effluent limitations and new source performance standards to be achieved through the application of identified treatment and control technologies.

An extensive search for information and data for mills within the above subcategories resulted in a very broad data base. Information and data were gathered from all possible sources including mill records, waste water sampling surveys, technical and trade associations, literature, NPDES permit applications, and interviews with industry authorities. The effluent limitations and performance standards were based upon extensive analysis of the accumulated information and data as described above. Identification of the technology levels of BPCTCA, BATEA, and NSPS were made and effluent qualities which could be achieved by each of the technologies were determined.

Evaluation of all available information and data resulted in the selection of the following significant waste water parameters for which limitations were developed:

Biochemical Oxygen Demand (five day-20°C) ($BOD_5$)
Total Suspended Solids (TSS)
pH
Color (not including Paperboard from Waste Paper Mills)
Ammonia Nitrogen (NSSC-Ammonia Base only)

Limitations have been set forth for $BOD_5$, TSS, and pH for July 1, 1977. The identified technologies of BPCTCA include good in-plant waste water management followed by external controls of preliminary screening, primary sedimentation, and biological treatment. The 1977 limitations can be met by mills using only secondary treatment, but a combination of in-plant controls and biological treatment may be more cost effective. It is estimated that increases in production costs to achieve the 1977 effluent limitations will range from less than $0.91 per metric ton ($1.00 per short ton) up to $12.70 per metric ton ($14.00 per short ton) depending upon specific mill conditions relating to available technologies at the particular mill.

Limitations have been set forth for $BOD_5$, TSS, and pH for July 1, 1983. Also, color limitations have been set forth for four subcategories. In addition, ammonia nitrogen limitations are recommended but not specified for one subcategory. The identified technologies of BATEA include in-plant waste water controls and secondary treatment. The identified in-plant controls may require some major changes in existing processes and design modifications to existing equipment. In addition, coagulation and filtration are identified for TSS reduction, and physical-chemical treatment is identified for color removal for four of the five subcategories. The estimated increases in production costs of upgrading existing mills from BPCTCA to BATEA range from less than $0.91 per metric ton ($1.00 per short ton) up to $6.35 per metric ton ($7.00 per short ton) depending upon specific mill conditions.

For new sources, standards have been set forth on $BOD_5$, TSS, and pH for all subcategories and color for two subcategories. The identified technologies for new sources includes in-plant waste water controls and external treatment. The external treatment consists of secondary treatment and for two subcategories, physical-chemical treatment for color reduction. The in-plant controls reflect internal improvements which can be achieved through effective design and layout of mill operations. The identified in-plant controls and external treatment systems are available for implementation as they have all been demonstrated at mills within the subcategories under study.

# SECTION II

# RECOMMENDATIONS

Based upon the technology described in this report, the following effluent limitations and standards of performance are for the subcategories studied.

## Best Practicable Control Technology Currently Available

The effluent limitations for best practicable control technology currently available (BPCTCA) are shown in Table 1.

Table 1

BPCTCA Effluent Limitations

Values in kg/kkg (lbs/ton)

| Subcategory | BOD5 30 Day | BOD5 Daily Max | TSS 30 Day | TSS Daily Max |
|---|---|---|---|---|
| Unbleached Kraft | 2.8 (5.6) | 5.6 (11.2) | 6.0 (12.0) | 12.0 (24.0) |
| NSSC-Ammonia | 4.0 (8.0) | 8.0 (16.0) | 5.0 (10.0) | 10.0 (20.0) |
| NSSC-Sodium | 4.35(8.7) | 8.7 (17.4) | 5.5 (11.0) | 11.0 (22.0) |
| Unbleached Kraft-NSSC | 4.0 (8.0) | 8.0 (16.0) | 6.25(12.5) | 12.5 (25.0) |
| Paperboard from Waste Paper | 1.5 (3.0) | 3.0 (6.0) | 2.5 (5.0) | 5.0 (10.0) |

pH for all subcategories shall be within the range of 6.0 to 9.0

The maximum average of daily values for any 30 consecutive day period should not exceed the 30 day effluent limitations shown above. The maximum for any one day should not exceed the daily maximum effluent limitations as shown above. The limitations shown above are in kilograms of pollutant per metric ton of production (pounds of pollutant per short ton of production). Production is defined as the annual average production off the machine (air dry tons). Effluents should always be within the pH range of 6.0 to 9.0.

The TSS parameter is measured by the technique utilizing glass fiber filter disks as specified in Standard Methods for the Examination of Water and Wastewater (13th Edition) (1).

## Best Available Technology Economically Achievable

The effluent limitations for best available technology economically achievable (BATEA) are shown in Table 2.

Table 2

BATEA Effluent Limitations

Values in kg/kkg (lbs/ton)

| Subcategory | BOD5 | | TSS | |
|---|---|---|---|---|
| | 30 Day | Daily Max | 30 Day | Daily Max |
| Unbleached Kraft | 1.35 (2.7) | 2.7 (5.4) | 1.85 (3.7) | 3.7 (7.4) |
| NSSC - Ammonia | 3.2 (6.4) | 6.4 (12.8) | 2.6 (5.2) | 5.2 (10.4) |
| NSSC - Sodium | 2.25 (4.5) | 4.5 (9.0) | 2.5 (5.0) | 5.0 (10.0) |
| Unbleached Kraft - NSSC | 1.6 (3.2) | 3.2 (6.4) | 2.1 (4.2) | 4.2 (8.4) |
| Paperboard from Waste Paper | 0.65 (1.3) | 1.3 (2.6) | 0.8 (1.6) | 1.6 (3.2) |

| Subcategory | Color | |
|---|---|---|
| | 30 Day | Daily Max |
| Unbleached Kraft | 10 (20) | 15 (30) |
| NSSC - Ammonia | 75 % removal | |
| NSSC - Sodium | 75 % removal | |
| Unbleached Kraft - NSSC | 12.5 (25) | 18.75 (37.5) |
| Paperboard from Waste Paper | - | - |

pH for all subcategories shall be within the range of 6.0 to 9.0

The maximum average of daily values for any 30 consecutive day period should not exceed the 30 day effluent limitations shown above. The maximum for any one day should not exceed the daily maximum effluent limitations shown above. The limitations are in kilograms of pollutant per metric ton of production (pounds of pollutant per short ton of production). Production is defined as the annual average production off the machine (air-dry-tons). Effluents should always be within the pH range of 6.0 to 9.0.

Effluent limitations are needed for ammonia nitrogen for NSSC-ammonia base mills only. However, no specific limitations have been established because of the extreme lack of meaningful data, and because of the lack of applied technology for ammonia nitrogen removal at the concentrations cited. Currently, only two such mills exist and preliminary indications are that discharges in the range of 7.5-10.0 kg/kkg (15-20 lbs/ton) can occur. No technology for the removal of nitrogen has been applied within the pulp and paper industry, and only very limited technology has been applied in other industries, especially at the concentrations cited. Extensive studies on effective methods for the removal of nitrogen in these concentrations must be carried out before specific effluent limitations can be established.

The TSS parameter is measured by the technique utilizing glass fiber filter disks as specified in Standard Methods for the Examination of Water and Wastewater (13th Edition) (1).

The color parameter is measured by the NCASI testing method as described in NCASI Technical Bulletin #253 (See Appendix V) (2). The above color limitations of 75% removal for both sodium and ammonia base NSSC will be changed to kilograms of color per metric ton of production (pounds of color per short ton of production) at a later date when the color removal technologies have been proven through further development. Color units are to be assumed equal to mg/l in determining kilograms (pounds) of color per metric ton (short ton) of production.

## New Source Performance Standards

The new source performance standards (NSPS) are shown in Table 3.

Table 3

New Source Performance Standards

Values in kg/kkg (lbs/ton)

| Subcategory | BOD$_5$ | | TSS | |
|---|---|---|---|---|
| | 30 Day | Daily Max | 30 Day | Daily Max |
| Unbleached Kraft | 1.55 (3.1) | 3.1 (6.2) | 3.75 (7.5) | 7.5 (15.0) |
| NSSC - Ammonia | 3.75 (7.5) | 7.5 (15.0) | 3.75 (7.5) | 7.5 (15.0) |
| NSSC - Sodium | 2.6 (5.2) | 5.2 (10.4) | 3.85 (7.7) | 7.7 (15.4) |
| Unbleached Kraft - NSSC | 1.9 (3.8) | 3.8 (7.6) | 4.0 (8.0) | 8.0 (16.0) |
| Paperboard from Waste Paper | 0.75 (1.5) | 1.5 (3.0) | 2.0 (4.0) | 4.0 (8.0) |

| Subcategory | Color | |
|---|---|---|
| | 30 Day | Daily Max |
| Unbleached Kraft | 10 (20) | 15 (30) |
| NSSC - Ammonia | - | - |
| NSSC - Sodium | - | - |
| Unbleached Kraft - NSSC | 12.5 (25) | 18.75 (37.5) |
| Paperboard from Waste Paper | - | - |

pH for all subcategories shall be within the range of 6.0 to 9.0

The maximum average of daily values for any 30 consecutive day period should not exceed the 30 day standards shown above. The maximum for any one day should not exceed the daily maximum standards shown above. The standards are in kilograms of pollutant per metric ton of production (pounds of pollutant per short ton of production). Production is defined as the annual average production off the machine (air-dry-tons). Effluents should always be within a pH range of 6.0 to 9.0.

The TSS parameter is measured by the technique utilizing glass fiber filter disks as specified in Standard Methods for the Examination of Water and Wastewater (13th Edition) (1).

The color parameter is measured by methods described in NCASI Technical Bulletin #253 (See Appendix V) (2). Color units are to be assumed equal to mg/l in determining kilograms (pounds) of color per metric ton (short ton) of production.

## SECTION III

## INTRODUCTION

### PURPOSE AND AUTHORITY

Section 301(b) of the Federal Water Pollution Control Act, as amended in 1972, requires the achievement by not later than July 1, 1977, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best practicable control technology currently available as defined by the Administrator pursuant to Section 304(b) of the Act. Section 301(b) also requires the achievement by not later than July 1, 1983, of effluent limitations for point sources, other than publicly owned treatment works, which are based on the application of the best available technology economically achievable which will result in reasonable further progress toward the national goal of eliminating the discharge of all pollutants, as determined in accordance with regulations issued by the Administrator pursuant to Section 304(b) of the Act. Section 306 of the Act requires the achievement by new sources of a Federal standard of performance providing for the control of the discharge pollutants which reflects the greatest degree of effluent reduction which the Administrator determines to be achievable through the application of the best available demonstrated control technology, processes, operating methods, or other alternatives, including, where practicable, a standard permitting no discharge of pollutants.

Section 304(b) of the Act requires the Administrator to publish within one year of enactment of the Act, regulations providing guidelines for effluent limitations setting forth the degree of effluent reduction attainable through the application of the best control measures and practices achievable including treatment techniques, process and procedure innovations, operation methods, and other alternatives. The regulations proposed herein set forth effluent limitations guidelines pursuant to Section 304(b) of the Act for the unbleached kraft, neutral sulfite semi-chemical (NSSC), and paperboard from waste paper segments of the pulp, paper, and paperboard point source categories.

Section 306 of the Act requires the Administrator, within one year after a category of sources is included in a list published pursuant to Section 306(b)(1)(A) of the Act, to propose regulations establishing Federal standards of performance for new sources within such categories. The Administrator published in the Federal Register of January 16, 1973, (38 FR 1624), a list of 27 source categories. Publication of the list constituted announcement of the Administrator's intention of establishing, under Section 306, standards of performance applicable to new sources within the pulp, paper, and paperboard point source categories, which were included within the list published January 16, 1973.

The limitations in this document identify (in terms of chemical, physical, and biological characteristics of pollutants) the level of

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pollutant reduction attainable through the application of the best practicable control technology currently available and the best available technology economically achievable. The limitations also specify factors which must be considered in identifying the technology levels and in determining the control measures and practices which are to be applicable within given industrial categories or classes.

In addition to technical factors, the Act requires that a number of other factors be considered, such as the costs or cost-benefit study and the nonwater quality environmental impacts (including energy requirements) resulting from the application of such technologies.

## SUMMARY OF METHODS USED FOR DEVELOPMENT OF THE EFFLUENT LIMITATIONS GUIDELINES AND STANDARDS OF PERFORMANCE

The basic procedures used in developing the effluent limitations and standards of performance are discussed below.

The unbleached pulping segments, exclusive of groundwood, acid sulfite, and soda pulping segments, of the pulp and paper industry were subcategorized based on an evaluation of available data in terms of raw materials, process differences, waste loads, products produced, age and size of mills, and geographical locations. The resultant subcategories include:

1. Unbleached kraft
2. Neutral sulfite semi-chemical (NSSC) - Sodium base
3. NSSC - Ammonia base
4. Unbleached kraft - NSSC (Cross Recovery)
5. Paperboard from Waste Paper

### Summary Discussion of Data Sources

The extensive data and information base which was used in the development of the effluent limitations was generated by the methods discussed below. The sources of data and information included the following:

1. Mill records
2. National Council for Air and Stream Improvement, Inc. (NCASI), specifically Special Reports 73-02 (3) and 73-03 (4)
3. American Paper Institute (API)
4. Short term verification survey results
5. EPA National Pollutant Discharge Elimination System (NPDES) Applications
6. Literature
7. Personal interviews with recognized authorities in the pulp and paper industry.

### Mill Records

Data were accumulated from mill records which covered in most cases at least 12-13 months operating time. Most of the mill data were a result of daily sampling and analysis. The mill data were carefully screened in order to have an accurate set of data for each mill. For many of the mills, a survey of sampling and analytical techniques was made in order to determine the validity of the data. In addition, many mill waste waters were also sampled for a period of 3-7 days with samples being split between the mill laboratory and the contractor's laboratory.

## NCASI

NCASI Special Reports 73-02 (3) and 73-03 (4) presented suspended solids and $BOD_5$ data for mills using activated sludge or aerated stabilization basins treatment systems, respectively. The NCASI carefully screened the data before inclusion in the publications. The data were from mill records and represented an average of a year's operation.

## API

The API provided EPA data and information as a result of coordination of industry comments and technical meetings between the API and EPA.

## Short Term Surveys

As mentioned previously, surveys were conducted of several mills for 3-7 days with a basic objective of evaluation of mill data. Twenty-four hour composites of hourly samples were taken of the mills' waste water during the surveys. Sampling and analytical techniques were conducted using EPA accepted procedures. It should be noted that the resulting data was not directly utilized in determining effluent limitations because of the short duration of the surveys. The main objective of the surveys was to determine the validity of the mills' data.

## NPDES Applications

Data from NPDES applications represent an average operating condition for the mills. The data frequently does not compare to data from other sources for the same mills. Thus, the NPDES data was only used as a comparison check to other data.

## Literature

Frequently, the mill effluent data in published literature are not correlated with the particular mill which the data represents. Also, the reliability of the data are sometimes questionable since sampling and analytical methods are usually not presented and the time frame which the data represents is frequently omitted. Thus, mill effluent data from literature sources were not directly used in determining the effluent limitations. However, the information and data presented in literature do provide information on the most recent pollution control technologies, and these sources were used as background information.

## Use of Information and Data to Develop Effluent Limitations Guidelines

With the objective to identify mills which could be considered as representing the best existing practicable control technology, a list of every mill in each of the subcategories was compiled and is shown in Appendix I. All available information regarding the internal processes employed, types of products, waste treatment facilities in operation, and quantity/quality of the waste water discharge was then tabulated for each mill.

The above information was evaluated to determine which mills should be investigated further by on-site surveys. The main criteria used during the evaluation was the quantity of waste water discharge and quality of the discharge as characterized by $BOD_5$ and suspended solids. The former tended to indicate the extent of in-plant control practices and the latter the extent and performance capabilities of waste treatment facilities. This effort resulted in a list of mills which included ten unbleached kraft mills, six NSSC mills, seven combination kraft-NSSC mills, and twelve paperboard from waste paper mills.

Other factors, such as production mix, age of mill, type of raw materials used, type of digester and recovery systems, and reliability of daily treatment records were then weighed to select mills for on-site surveys as candidate mills exhibiting best demonstrated performance. This procedure further reduced the list of potential candidates to 14 in the pulping subcategories and 10 in the paperboard from waste paper subcategory.

Prior to sending a sampling survey team to the above mills, a reconnaissance team was sent to the mills selected from the above list. At that time the mill personnel were briefed on the objectives of the project, the information that was necessary for the successful completion of the project, and the work program to be carried out by the sampling survey team. A copy of the reconnaissance and mill survey questionnaires is shown in Appendix IV. At that time the availability of laboratory facilities, and the feasibility of obtaining verification data by a field survey were determined. A tour of the plant and the treatment facilities, and a review of the available mill records on waste streams, both internal and external, were made. The objective of this effort was to verify that the mill was a candidate mill exhibiting best demonstrated performance and that the mill records could be validated by a field survey team. The type of cost records and information required for the project was described at this time so that the mill would have the time to compile the information which was required by the sampling survey team. The pre-survey visit eliminated three candidate mills from the survey effort for the following reasons:

flood conditions at one mill made it impossible to obtain good flow measurements of the waste stream; and two mills were engaged in major construction in the pulp mill which exerted an abnormal influence on the waste water generated.

The field survey team consisted of three to seven people, depending on the particular mill studied. The goal was to obtain analytical and flow data on various in-plant controls and external treatment systems. Samples were collected every hour and composited every 24 hours for three to seven days. During the survey, composited samples were split between the mill laboratory personnel and the survey team. Samples were analyzed on-site by the survey team or by an independent laboratory. All analyses were performed following methods described in Standard Methods for the Examination of Water and Wastewater (13th Edition) (1) or equivalent EPA accepted methods (See Appendix IV, Exhibit 2). A typical example of the results is tabulated in Table 4. One objective of this effort was to generate an "analytical procedure factor" to be applied to the 12 month data collected from the mill. This was to attempt to place all data from all surveyed mills on the same analytical base. The biggest variation and most difficulty experienced in this procedure was in suspended solids since some mills used filter paper with a funnel and others used asbestos or fiberglass pads with a gouch crucible. In almost all mills, the comparative $BOD_5$ values fell within the limits of accuracy of the test. However, development of the "analytical factor" did not prove to be feasible because of the wide variations in testing procedures and much of the data did not correlate between procedures.

The 12-month mill data, subject to any cautions indicated from the testing procedures, were used as the basis of a broad based data bank for each of the subcategories under study. The tons per day of production for each mill was corrected to air dry tons (ADT) as required. Some mill data for raw waste load were found not to include all waste water discharges and corrections to the data were made where necessary. The data were generally developed from 12 months of daily records from each mill. The data presented in the following sections are believed to be in accordance with accepted standards of the analytical procedures verified by survey programs with an exception for total suspended solids data which includes some mill data which were determined by non-standard methods. The procedure used to develop the suspended solids data presented in this report is identified as to (1) Standard Methods (SM) which is the result of EPA accepted analytical procedures or (2) Non-Standard Methods (NSM) which is the result of analytical techniques not following EPA accepted procedures. The NSM data is presented but was not used in determining effluent limitations.

In addition to the above accumulated data and information, the full range of control and treatment technologies existing within each subcategory was identified. This included an identification of each distinct control and treatment technology, including both in-plant and end-of-process technologies, which are existent or capable of being

Table 4

**Short Term Survey Data Comparison**
(Mill UK-2)

| Date: May 1973 | Analysis BY | Raw Waste BOD5 | Raw Waste TSS | Raw Waste pH | Raw Waste Color | Primary Effluent BOD5 | Primary Effluent TSS | Primary Effluent pH | Primary Effluent Color | Secondary Effluent BOD5 | Secondary Effluent TSS | Secondary Effluent pH | Secondary Effluent Color | Final Effluent BOD5 | Final Effluent TSS | Final Effluent pH | Final Effluent Color |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 7 | Mill | 330 | NA | 10.5 | NA | 430 | NA | 9.5 | NA | 130 | NA | 8.0 | NA | 34 | NA | 7.4 | NA |
| | EPA | 265 | NA | NA | NA | 331 | NA | NA | NA | 104 | NA | NA | NA | 30.5 | NA | NA | NA |
| 8 | Mill | 400 | 547 | 8.7 | 290 | 430 | 478 | 9.7 | 540 | 130 | 109 | 8.0 | 360 | 33 | 83 | 7.9 | 400 |
| | EPA | 280 | 270 | NA | 680 | 302 | 66 | 10.2 | 400 | 118 | 34 | 8.4 | 270 | 36 | 64 | 8.2 | 230 |
| 9 | Mill | NA | 632.8 | 8.3 | 220 | 240 | 151 | 9.8 | 290 | 110 | 115 | 9.1 | 470 | 21 | 77 | 8.4 | 400 |
| | EPA | 232 | 637 | NA | 130 | 282 | 332 | 9.3 | 230 | 115 | 91 | 8.4 | 340 | 24.7 | 66 | 7.8 | 448 |
| 10 | Mill | 260 | 384 | 10.4 | 330 | 250 | 144 | 9.3 | 220 | 130 | 120 | 8.0 | 440 | 22 | 163 | 7.6 | 400 |
| | EPA | 268 | 534 | NA | 220 | 299 | 476 | 9.6 | 560 | 112 | 125 | 8.0 | 560 | 26 | 89 | 8.0 | 700 |

Units: Color - APHA Color units
pH - pH values
TSS, BOD5 - milligrams per liter

designed for each subcategory. It also included an identification in terms of the amount of constituents and the chemical, physical, and biological characteristics of pollutants, of the effluent level resulting from the application of each of the treatment and control technologies. The problems, limitations, and reliability of each treatment and control technology and the required implementation time were also identified. In addition, the nonwater quality environmental impact, such as the effects of the application of such technologies upon other pollution problems, including air, solid waste, noise, and radiation was also identified. The energy requirements of each of the control and treatment technologies were identified as well as the cost of the application of such technologies.

The information, as outlined above, was then evaluated to determine the best practicable control technology currently available; best available technology economically achievable; and the best available demonstrated control technology processes, operating methods, or other alternatives. In identifying such technologies, various factors were considered. These included the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application, the age and size of equipment and facilities involved, the process employed, the engineering aspects of the application of various types of control techniques or process changes, non-water quality environmental impact (including energy requirements), and other factors.

The accumulation of data from the above sources resulted in a large data base and is presented in Table 5. As shown in the table, the total number of mills included in the subcategories under study is 218 of which approximately 83 discharge to municipal systems. Of the 135 mills discharging to receiving waters, raw waste data from mill records was available for 64 mills. Final effluent data for mills which have biological treatment systems were available for 30 mills.

All of the above sources were used in developing the effluent limitations. However, it should be pointed out that the data sources are not equal in reliability and thus, they were weighted accordingly. The data from mill records were used as the major source in conjunction with data from the NCASI publications and the API. Data from these three sources were used as the basis for the effluent limitations. The data from other sources were used mainly as backup data from which to check the accumulated data. The short term survey data represents essentially a little more than one data point over a year's time and thus should be within the range of the year's operating data. The NPDES data were used as a comparison check. Data from literature were used as background information.

## GENERAL DESCRIPTION OF INDUSTRY SEGMENTS

Paper is made from raw materials which contain adequate amounts of cellulose fiber. The cellulose fibers must first be separated from

## TABLE 5

### NUMBER OF MILLS PER SOURCE OF INFORMATION

| Subcategory | Total Number of Mills | Discharging To Municipal | Discharging To Receiving Waters | NPDES Applications | Literature | Sampling Surveys | Mill Records, NCASI | | Best Performers |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Raw Waste | Final Effluent[a] | |
| Unbleached Kraft | 27 | 0 | 27 | 23 | 14 | 4 | 24 | 12 | 6 |
| NSSC-Sodium | 14 | 1 | 13 | 12 | 13 | 1 | 6 | 3 | 1 |
| NSSC-Ammonia | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 1 | 0 |
| Kraft-NSSC | 10 | 0 | 10 | 10 | 0 | 2 | 10 | 4 | 3 |
| Paperboard-Waste Paper | 165 | 83 | 82 | 16 | 42 | 4 | 23 | 9[b] | 8 |
| Totals | 218 | 84 | 134 | 62 | 69 | 12 | 64 | 30 | 18 |

(a) Effluents from biological treatment
(b) One of the nine mills only had primary treatment

other constituents of the fiber source and fiberized. This function is the pulping process. During the 19th century, the use of wood began to supplant cotton and linen rags, straw, and other less plentiful fiber sources. Today, wood pulp accounts for over 98 percent of the virgin fiber used in papermaking.

There are several methods used for pulping wood. In some, it is cooked with chemicals under controlled conditions of temperature, pressure, time, and pulping liquor composition (5). The various processes utilize different chemicals or combinations of them. In other methods, wood is reduced to a fibrous state by mechanical means or a combination of chemical and mechanical action. The repulping of waste paper is a hydraulic and mechanical process.

The early use of kraft pulping, an alkaline chemical process, was concurrent with the ascendancy of wood as a papermaking raw material. The process was first patented in this country more than 100 years ago and is currently the dominant pulping method accounting for nearly 58% of the total industry production. Table 6 shows production figures for the segments of the pulp and paper industry. Kraft pulping is the dominant pulping method largely for two reasons: 1) Recovery, because of the cost of the chemicals utilized, is an economic necessity to the process and in the 1930's successful chemical recovery techniques were applied; 2) The process was found to be adaptable to nearly all wood species and its application to southern yellow pines, which were unsuitable for other processes, resulted in a rapid expansion of kraft pulping (6).

The principles basic to the neutral sulfite semi-chemical process -1) chemical treatment of chips followed by grinding or fiberizing and 2) cooking with a neutral or slightly alkaline sodium sulfite solution -- were also advanced in the 19th century. However, it was not until their advantages were demonstrated in the 1920's at the U.S. Forest Products Laboratory that the first NSSC mill began operation in 1925 for the production of corrugating board (6). The process gained rapid acceptance particularly because of its ability to utilize the vast quantities of inexpensive hardwoods previously considered unsuitable for producing quality pulps (7). Also, the quality of stiffness which hardwood NSSC pulps impart to corrugating board (6), and the large demand for this material, have promoted a rapid expansion of the process.

The future of NSSC pulping is closely tied to the development of economic systems for chemical recovery or nonpolluting chemical disposal. In the past, the small size of the mills, the low organic content and heat value of the spent liquor, and the low cost of cooking chemicals provided little incentive for large capital investment for recovery plants (6).

Waste paper has been recycled in this country since the mid-1850's. Today, about 21 percent of the paper and paperboard produced is reused as a raw material for new products. In 1972, 11.4 million metric tons

(12.6 million short tons) were reclaimed. Paperboard from waste paper mills consumed about 75 percent of this total (8).

## Table 6

## Pulp and Paper Industry

## Pulp Production (excluding builders board)

| Pulp & Paper Segments | Metric Tons/year | (Tons/Year) | % of Production |
|---|---|---|---|
| Groundwood pulp | 4,188,000 | (4,617,000) | 8.9 |
| NSSC | 3,449,000 | (3,803,000) | 7.4 |
| Unbleached kraft | 15,677,000 | (17,285,000) | 33.6 |
| Unbleached kraft-NSSC | (*) | (*) | (*) |
| Bleached kraft | 11,220,000 | (12,371,000) | 24.0 |
| Bleached sulfite | 1,629,000 | (1,796,000) | 3.5 |
| Unbleached sulfite | 302,000 | (333,000) | 0.6 |
| Soda pulp | 127,000 | (140,000) | 0.2 |
| Paperboard from waste paper | 6,670,000 | (7,354,000) | 14.3 |
| Pulp from waste paper (**) | 3,507,000 | (3,867,000) | 7.5 |
| TOTALS | 46,770,000 | (51,566,000) | 100.0 |

(*) Production figures for Unbleached kraft-NSSC are reported in the separate values for unbleached kraft and NSSC.
(**) Used as furnish for the segments listed above (except paperboard from waste paper).

Sources of data:

a. Post's 1973 Pulp and Paper Directory.
b. API (verbal discussions).
c. State-of-the-Art Review of Pulp and Paper Waste Treatment-EPA

## Products

Unbleached kraft pulps are particularly suitable for producing linerboard which is a paperboard that is used as (1) the smooth surface facing in "corrugated" boxes, (2) wrapping paper, and (3) paper for grocery bags and shipping sacks. About 95 percent of NSSC pulp is used to manufacture the corrugated medium for corrugated boxes but it is also a component of other products which do not require the maximum tearing resistance or folding endurance such as white paper and newsprint (6). Paperboard made from waste paper is most familiar in a wide variety of commercial packaging which does require a folding capability, such as bottle carriers.

## Daily Production Capacity and Distribution

The 1973 industry data show that there are approximately 27 mills in the United States which produce nothing other than unbleached kraft pulp and paper and/or paperboard. Their total daily capacity is about 18,140 metric tons (20,000 short tons) for pulp and nearly 22,675 metric tons (25,000 short tons) for paper and board production. Sixteen separate NSSC mills with a total daily capacity of 5455 metric tons (6025 short tons) for producing pulp and 6004 metric tons (6620 short tons) for paper and board are recorded. The total daily capacity of ten unbleached kraft and NSSC mills operating with cross recovery is as follows:

Kraft pulp -- 8492 metric tons (9363 short tons)
NSSC pulp -- 1971 metric tons (2173 short tons)
Paperboard -- 9452 metric tons (10,421 short tons)

One hundred sixty-five paperboard from waste paper mills having a daily production capacity of about 19,047 metric tons (21,000 short tons) are also shown.

Mills which fall within these subcategories of the pulp and paper industry are listed in Appendix I.

The size range of these mills in terms of paper and board capacity is:

Unbleached Kraft -- 181-1701 metric tons (200-1875 short tons)
NSSC-Sodium -- 91-635 metric tons (100-700 short tons)
NSSC-Ammonia -- 453 - 508 metric tons (500 - 560 short tons)
Unbleached Kraft-NSSC -- 604-1905 metric tons (666-2100 short tons)
Paperboard from
Waste Paper -- 13.6-907 metric tons (15-1000 short tons)

The geographic distribution of the kraft and NSSC mills, and that of the joint kraft-NSSC operations, are shown in Figure 1. Figure 2 illustrates the distribution of the paperboard from waste paper mills.

## Annual Production

A total of over 15.4 million metric tons (17 million short tons) of unbleached kraft pulp and nearly 3.6 metric tons (4 million short tons) of NSSC pulp were produced in the United States in 1972 according to preliminary American Paper Institute (API) statistics. Total unbleached kraft paper and paperboard production was 15.6 million metric tons (17.2 million short tons); NSSC paperboard, 3.6 million metric tons (4.0 million short tons); and paperboard from waste paper, 6.9 million metric tons (7.6 million short tons) (9). These totals include production of mills which manufacture other products in addition to those to which this report is addressed.

# PULP AND PAPERMAKING PROCESSES

## Unbleached Kraft

Wood, the fiber raw material of unbleached kraft pulp, arrives at the pulp mill as logs or as chips. Barked logs can be chipped directly for use. Bark is removed from unbarked logs in a wet or dry process and the logs are then chipped for conveyance to the digester, a large steel pressure vessel heated with steam to about 150°C. Here the chips are cooked in either a batch or continuous operation to dissolve lignin and separate the cellulosic fibers. The cooking liquor contains a mixture of caustic soda and sodium sulfide, which necessitate, because of high chemical costs and high liquor concentrations, a chemical recovery system which is integral to the process. This system and its role in the preparation of cooking liquor are described in ensuing paragraphs.

The unbleached kraft process is described as a "full-cook" process since cooking is completed to the point at which the wood will be fiberized upon being blown from the digester. In modern practice, the pulp is ejected to a blowtank.

The pulp, along with the "spent cooking liquor" is then transferred to a "brown-stock" chest, or tank, and thence to vacuum drum washers or continuous diffusers where the spent cooking liquor is separated by counter-current washing. In older mills, the pulp is "blown" directly to the diffusers from the digester.

Figure 1

DISTRIBUTION OF UNBLEACHED KRAFT, NSSC, AND KRAFT-NSSC MILLS IN THE U.S. (1973)

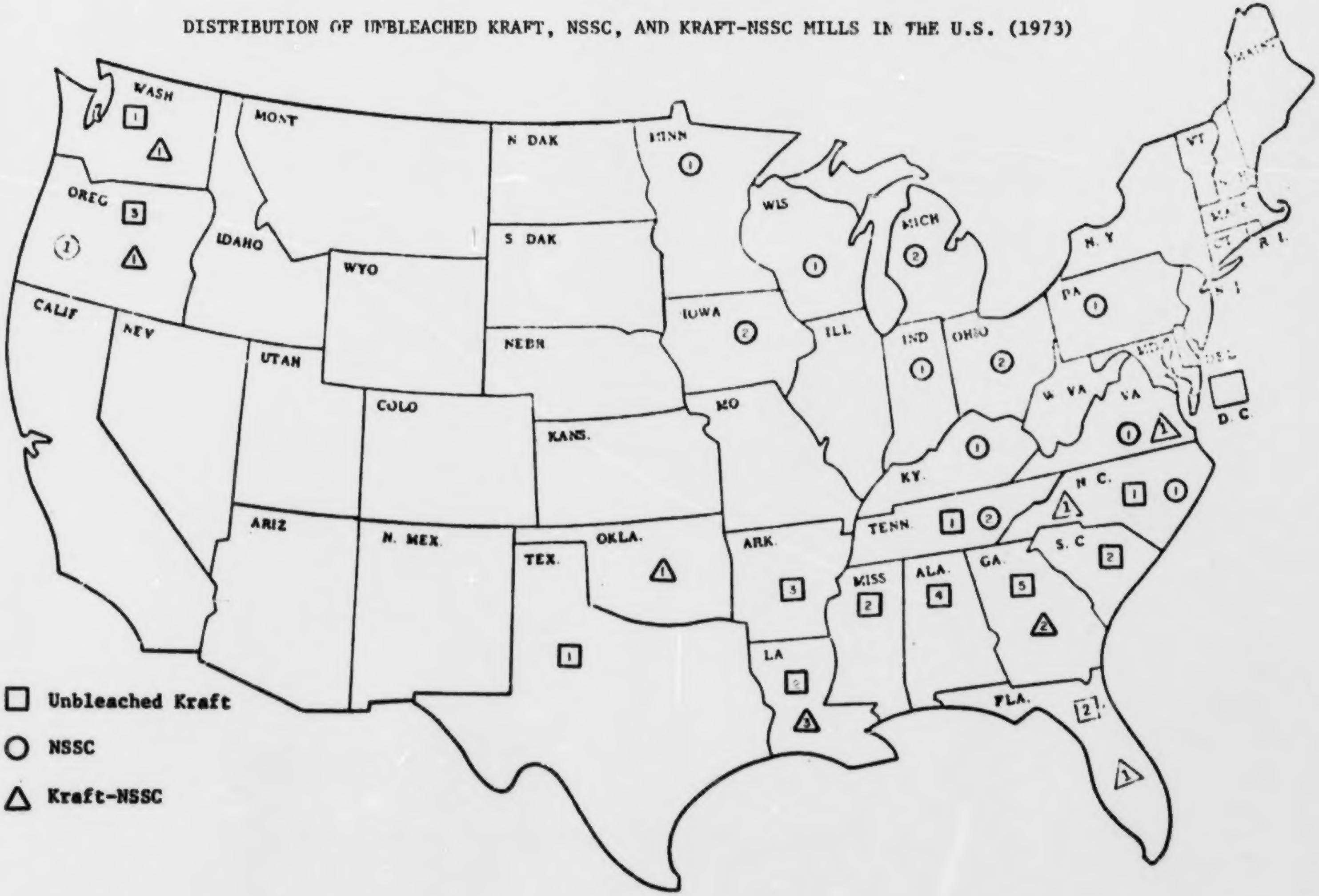
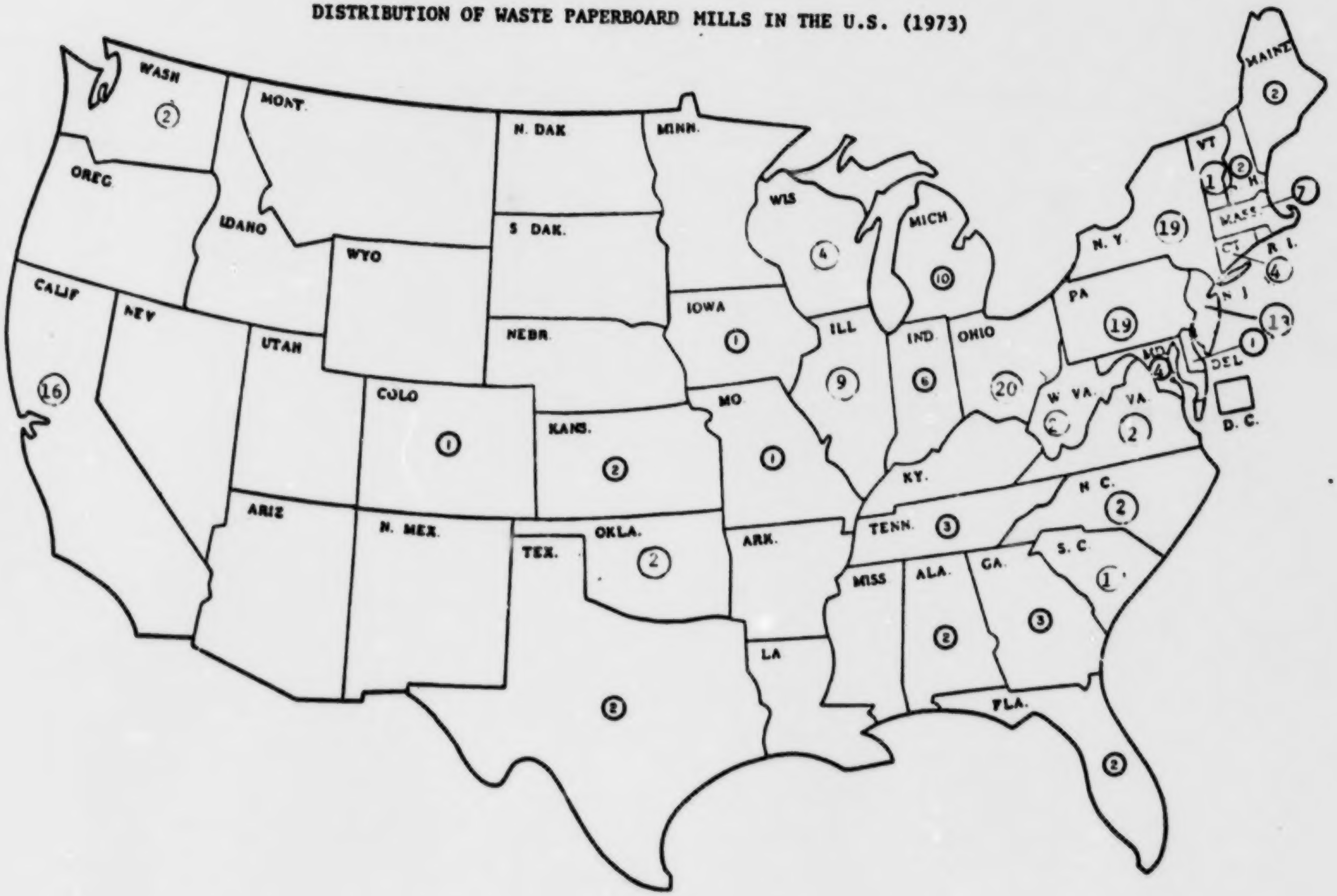

WASH
1
1
MONT
N DAK
MINN
1
WIS
1
MICH
2
N. Y
VT
R I.
OREG
3
1
1
IDAHO
WYO
S DAK
IOWA
2
ILL
IND
1
OHIO
2
PA
1
CALIF
NEV
UTAH
NEBR
MO
W VA
VA
1
1
D. C.
COLO
KANS.
KY.
1
N C.
1
1
1
TENN
1
2
ARIZ
N. MEX.
TEX.
1
OKLA.
1
ARK.
3
MISS
2
ALA.
4
GA.
5
2
S. C
2
LA
2
3
FLA.
2
1
Unbleached Kraft
NSSC
Kraft-NSSC

Figure 2

DISTRIBUTION OF WASTE PAPERBOARD MILLS IN THE U.S. (1973)


WASH
2
MONT.
N. DAK
MINN.
MAINE
2
VT
1
2
N. H
7
MASS.
OREG
IDAHO
S. DAK.
WIS
4
MICH
10
N. Y.
19
CT
R. I.
4
WYO
IOWA
1
PA
19
N. J
13
1
CALIF
NEV
UTAH
NEBR.
ILL
9
IND
6
OHIO
20
MD
4
DEL
D. C.
16
COLO
1
KANS.
2
MO
1
W. VA.
2
VA.
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KY.
N. C.
2
ARIZ
N. MEX.
TEX.
OKLA.
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ARK.
TENN.
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S. C.
1
MISS
ALA.
2
GA.
3
LA
2
FLA.
2

Chemical recovery necessitates a high degree of liquor separation with as little dilution as is possible to minimize heat requirements of evaporation (6)(10). Three stages of washing, which may employ blow tank condensate reuse are common but, in some cases, four are used. In some newer installations a combination of vacuum washers and diffusers is employed (11). Some continuous digesters contain liquor separation and diffusion washing zones within the digester body, and in many kraft mills,, the pulp is screened and/or refined prior to brown-stock washing to effect certain economies in washing and improvements in pulp quality (6).

After washing, the pulp is diluted and then screened to remove knots, uncooked chips, pitch particles, etc., and is ready for production of unbleached paper and paperboard or thickening to a high consistency for further processing, storage, or lapping for shipment.

The kraft pulping process is illustrated in Figure 3.

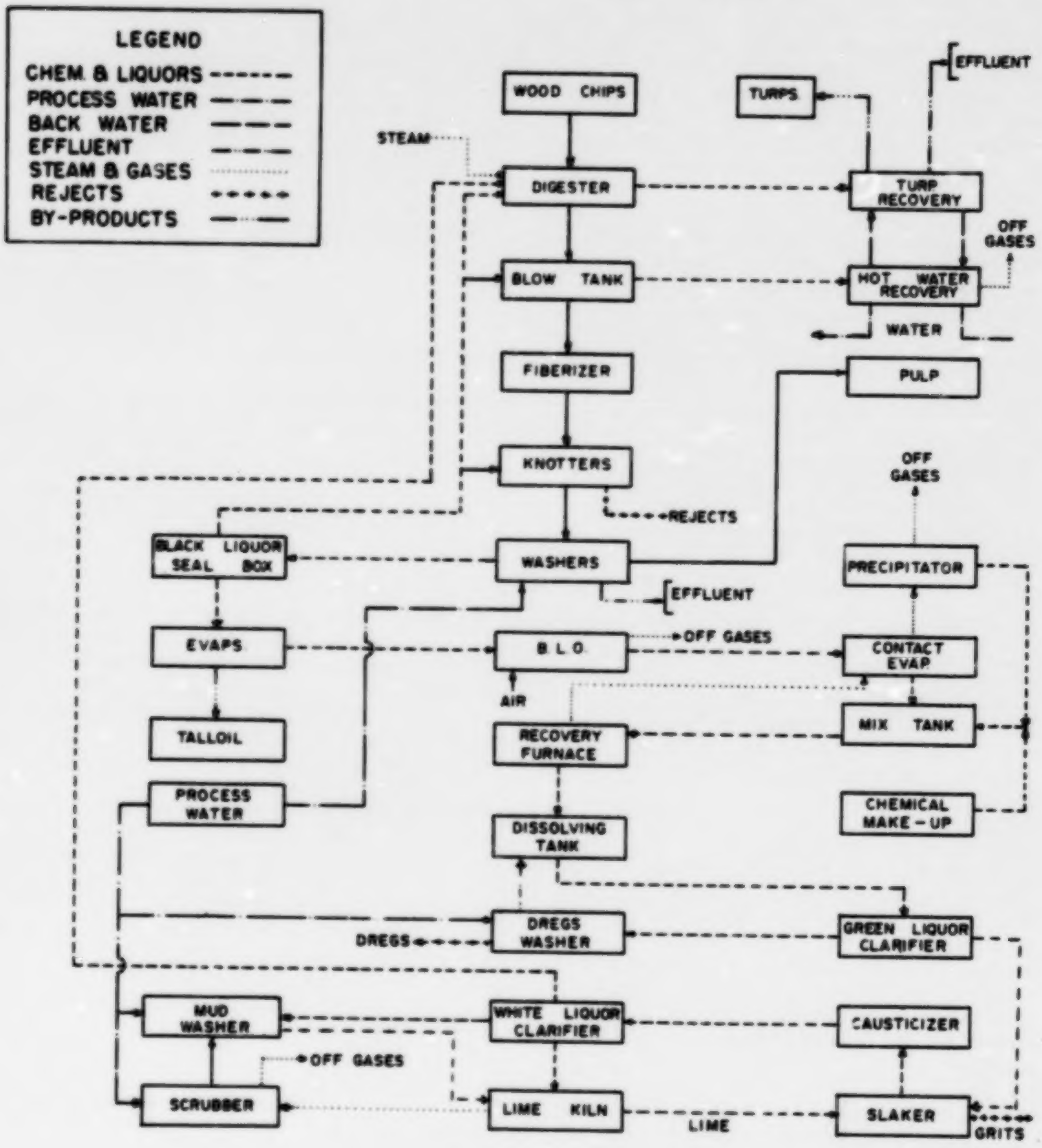
"Weak black liquor" comes from the washing operation and contains about 10-16 percent solids. In addition to the inorganic cooking chemicals, it contains organic wood constituents separated in the pulping process. The weak black liquor is concentrated to about 45 to 50 percent solids in long-tube multiple-effect evaporators and the resulting viscous mass is called "strong black liquor." This is then concentrated further to a consistency of 60 to 65 percent solids in the recovery furnace contact evaporator or in a concentrator.

Cooking chemicals lost in pulping and washing are replaced with a make-up chemical, usually sodium sulfate, or a residue with a high content of this salt (12). Acid sludge from oil treatment, raffinate from by-product production, NSSC waste liquor, and ash from incineration of NSSC liquor are examples of such residues. Salts captured from the recovery furnace stack gases are also reintroduced into the system. Sulfur and caustic soda are sometimes used to adjust the sulfidity.

The strong black liquor is then burned and the heat recovered in an especially designed boiler. During burning, the organic sodium compounds are converted to soda ash and sulfates reduced to sulfides on the floor or reducing section of the furnace. The molten smelt of salts is dissolved in water to form "green liquor." This is clarified by sedimentation and then causticized with lime to convert the soda ash to caustic soda. After causticizing, the combined $Na_2S$ - NaOH solution is known as "white liquor." This is settled and sometimes filtered through pressure filters, adjusted to the desired strength or concentration for cooking with weak black liquor, and stored for use in the pulping process.

The lime mud (calcium carbonate) obtained on settling this white liquor is washed and dewatered on rotary vacuum filters or centrifuges and burned in rotary or fluidized kilns to form quick lime. This is hy-

FIGURE 3 KRAFT PULPING PROCESS DIAGRAM


LEGEND
CHEM. & LIQUORS
PROCESS WATER
BACK WATER
EFFLUENT
STEAM & GASES
REJECTS
BY-PRODUCTS
WOOD CHIPS
TURPS
EFFLUENT
STEAM
DIGESTER
TURP RECOVERY
OFF GASES
BLOW TANK
HOT WATER RECOVERY
WATER
FIBERIZER
PULP
KNOTTERS
OFF GASES
REJECTS
BLACK LIQUOR SEAL BOX
WASHERS
PRECIPITATOR
EFFLUENT
EVAPS
B.L.O.
OFF GASES
CONTACT EVAP
AIR
TALLOIL
RECOVERY FURNACE
MIX TANK
PROCESS WATER
CHEMICAL MAKE-UP
DISSOLVING TANK
DREGS WASHER
GREEN LIQUOR CLARIFIER
DREGS
MUD WASHER
WHITE LIQUOR CLARIFIER
CAUSTICIZER
OFF GASES
SCRUBBER
LIME KILN
LIME
SLAKER
GRITS

drated with green liquor in slakers for reintroduction to the recovery cycle.

The kraft chemical recovery system is shown in Figure 4 (5).

## Paper Production

Paper is made by depositing, from a dilute water suspension of pulp, a layer of fiber on a fine screen which permits the water to drain through but which retains the fiber layer (6). This layer is then removed from the wire, pressed, and dried.

Two general types of machines and variations thereof are commonly employed. One is the cylinder machine in which the wire is placed on cylinders which rotate in the furnish, and the other is the fourdrinier in which the furnish is deposited upon an endless wire belt.

Generally, kraft paper is manufactured on fourdrinier machines and paperboard on either fourdrinier or cylinder machines. The primary operational difference between the two is the flat sheet-forming surface of the fourdrinier and the cylindrical-shaped mold of the cylinder machine. However, the type of machine used has little bearing on the raw waste load. The water which drains through the paper machine is known as white water and contains suspended fiber, pulp fines, and chemicals used as additives in the paper or board. In the case of unbleached kraft products, few additives are required other than alum and starch, and, in some bag and sack stock, wet-strength resins. The manufacture of linerboard involves a minimum of additives. It is, therefore, common to reuse white water from these operations, first in the paper and board making operation itself, and then in the pulping process. Fiber is collected and returned to the system.

The continuous paper sheet is sent through a series of pressing and drying machines before emerging as the basic product. A flow sheet of the fourdrinier operation is presented in Figure 5.

## NSSC Process

There are three main features of the NSSC process (13):

1. Impregnation of hardwood chips with cooking liquor
2. Cooking at high temperature
3. Mechanical fiberizing

While some mills buy the cooking chemical, it is more commonly prepared on the premises by burning sulfur and absorbing it in soda ash or ammonia, depending on which base is utilized. Newer mills employ continuous digesters although a large percentage of NSSC pulping still occurs in batch digesters which have been converted from other processes.

FIGURE 4

KRAFT PULPING CHEMICAL RECOVERY

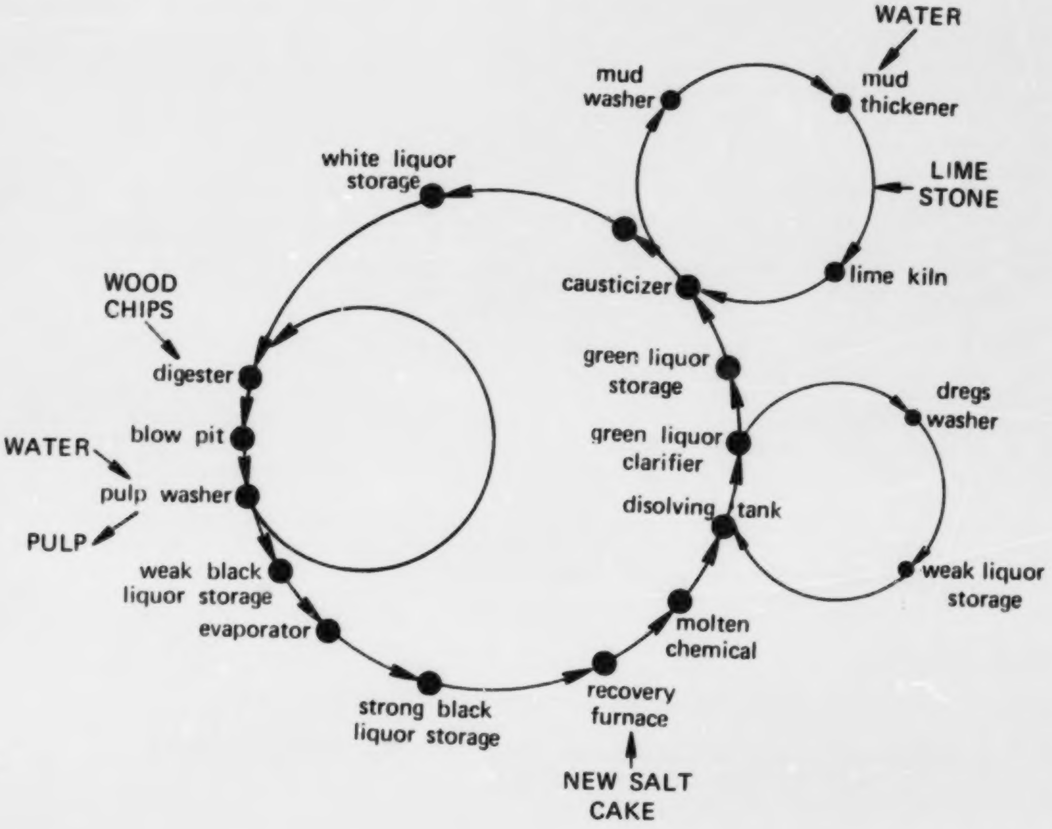
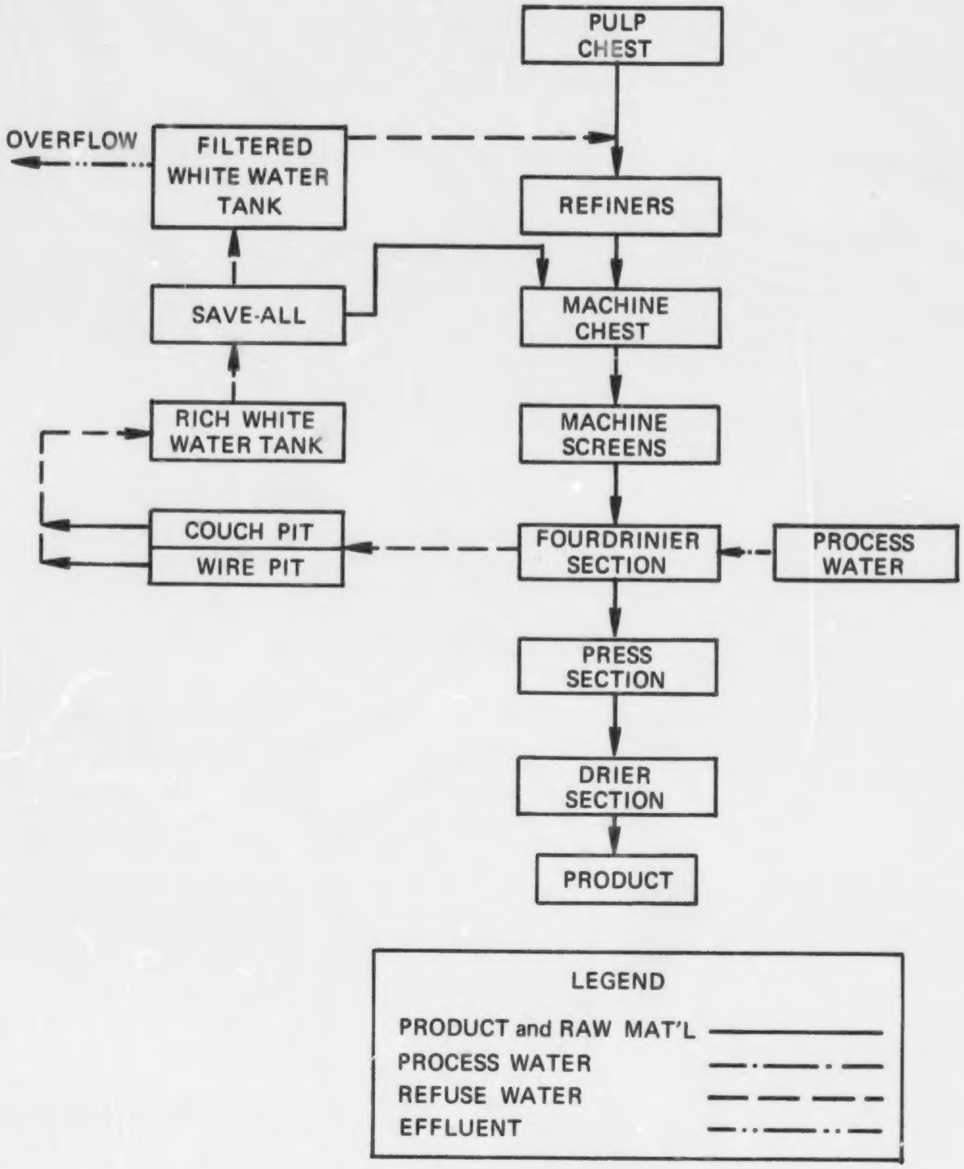

WATER
mud washer
mud thickener
white liquor storage
LIME STONE
causticizer
lime kiln
WOOD CHIPS
digester
green liquor storage
dregs washer
blow pit
WATER
green liquor clarifier
pulp washer
disolving tank
PULP
weak black liquor storage
weak liquor storage
evaporator
molten chemical
strong black liquor storage
recovery furnace
NEW SALT CAKE

FIGURE 5

## FOURDRINIER PAPER MACHINE PROCESS DIAGRAM


PULP CHEST
OVERFLOW
FILTERED WHITE WATER TANK
REFINERS
SAVE-ALL
MACHINE CHEST
RICH WHITE WATER TANK
MACHINE SCREENS
COUCH PIT
WIRE PIT
FOURDRINIER SECTION
PROCESS WATER
PRESS SECTION
DRIER SECTION
PRODUCT
LEGEND
PRODUCT and RAW MAT'L
PROCESS WATER
REFUSE WATER
EFFLUENT

Maximum temperature is adjusted according to retention time in the digester (13). A short cook, 10-20 minutes at approximately 200°C. is characteristic of screw digesters. In vertical or rotating spherical digesters, a period of one to three hours at temperatures ranging from 160°-175°C. is typical.

In some mills, the softened chips as they come from the digester are compressed in one or more stages of screw pressing. This facilitates maximum recovery of spent liquor and partial washing with minimum dilution (6). Either from this stage or directly from the digester they are sent to a disk mill for fiberizing. The chips then undergo vacuum or pressure washing, screening, and/or centrifugal cleaning. Digester relief and blow gases are condensed, and in some mills the condensate is used in pulp washing.

The pulp is conveyed to an agitated chest where it is diluted with white water from the paper mill to the desired consistency for feed to the secondary refiners servicing the papermaking operation. In making corrugating board, a small percentage of repulped waste paper is added to give the product desired characteristics.

The NSSC pulping process is illustrated in Figure 6.

## Recovery or Burning of Cooking Chemicals

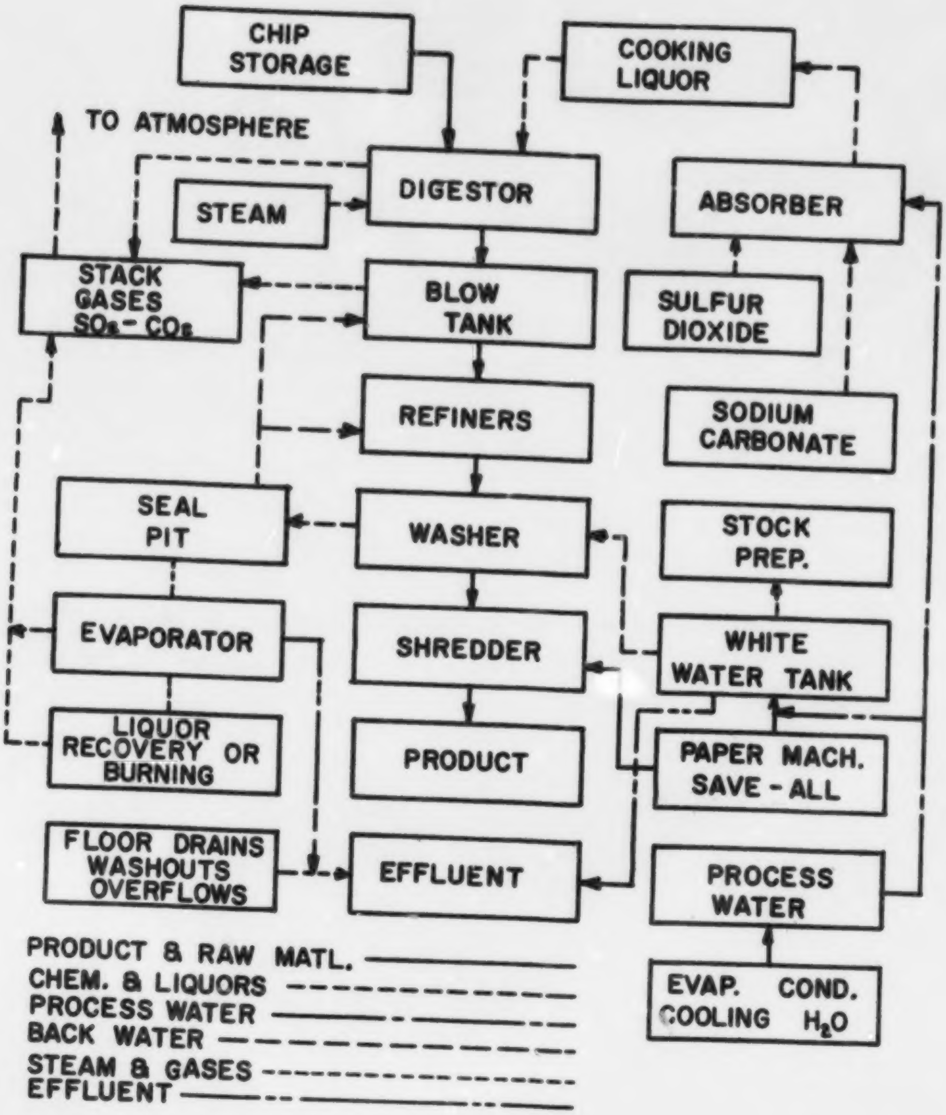
Chemical recovery in the sodium base NSSC process is considerably more difficult than in the kraft process. The spent liquor is low in solids with a relatively high proportion of inorganic to organic constituents, and, thus, does not burn easily. Other factors which complicate recovery are a relatively high liquor viscosity and relatively low sodium to sulfur ratio (5).

Because of these factors many mills simply evaporate and burn the spent liquor without recovery. Evaporation is commonly accomplished in multiple-effect evaporators. The concentrated liquor is burned for disposal or recovery in a fluidized bed reactor or a specially designed furnace. In sodium base mills, the fluidized bed combustion units produce sodium sulfate which is suitable for use in kraft mill liquor systems.

Recovery of sodium base NSSC liquor alone is presently limited to a few large mills. Three of the 14 sodium base NSSC mills under consideration in this report -- i.e., those which employ no other pulping processes -- have chemical recovery systems. Three others incinerate the liquor and two discharge to city sewers. For these mills, the simplest recovery practice, which is called "cross recovery", is to send the liquor to a nearby kraft recovery system.

No successful system has been developed for chemical recovery in ammonia base NSSC mills. In the two mills utilizing this base, the spent liquor

FIGURE 6
NEUTRAL SULFITE SEMI-CHEMICAL
PULP PROCESS DIAGRAM


CHIP STORAGE
COOKING LIQUOR
TO ATMOSPHERE
DIGESTOR
STEAM
ABSORBER
STACK GASES $SO_2 - CO_2$
BLOW TANK
SULFUR DIOXIDE
REFINERS
SODIUM CARBONATE
SEAL PIT
WASHER
STOCK PREP.
EVAPORATOR
SHREDDER
WHITE WATER TANK
LIQUOR RECOVERY OR BURNING
PRODUCT
PAPER MACH. SAVE - ALL
FLOOR DRAINS WASHOUTS OVERFLOWS
EFFLUENT
PROCESS WATER
EVAP. COND. COOLING $H_2O$
PRODUCT & RAW MATL.
CHEM. & LIQUORS
PROCESS WATER
BACK WATER
STEAM & GASES
EFFLUENT

is incinerated. The combustion products are gaseous with a negligible residue of inorganic ash (14) (15).

### Paper Production

Production of paper from NSSC pulp is similar to the operations in unbleached kraft mills as discussed previously.

### Kraft-NSSC (Cross Recovery)

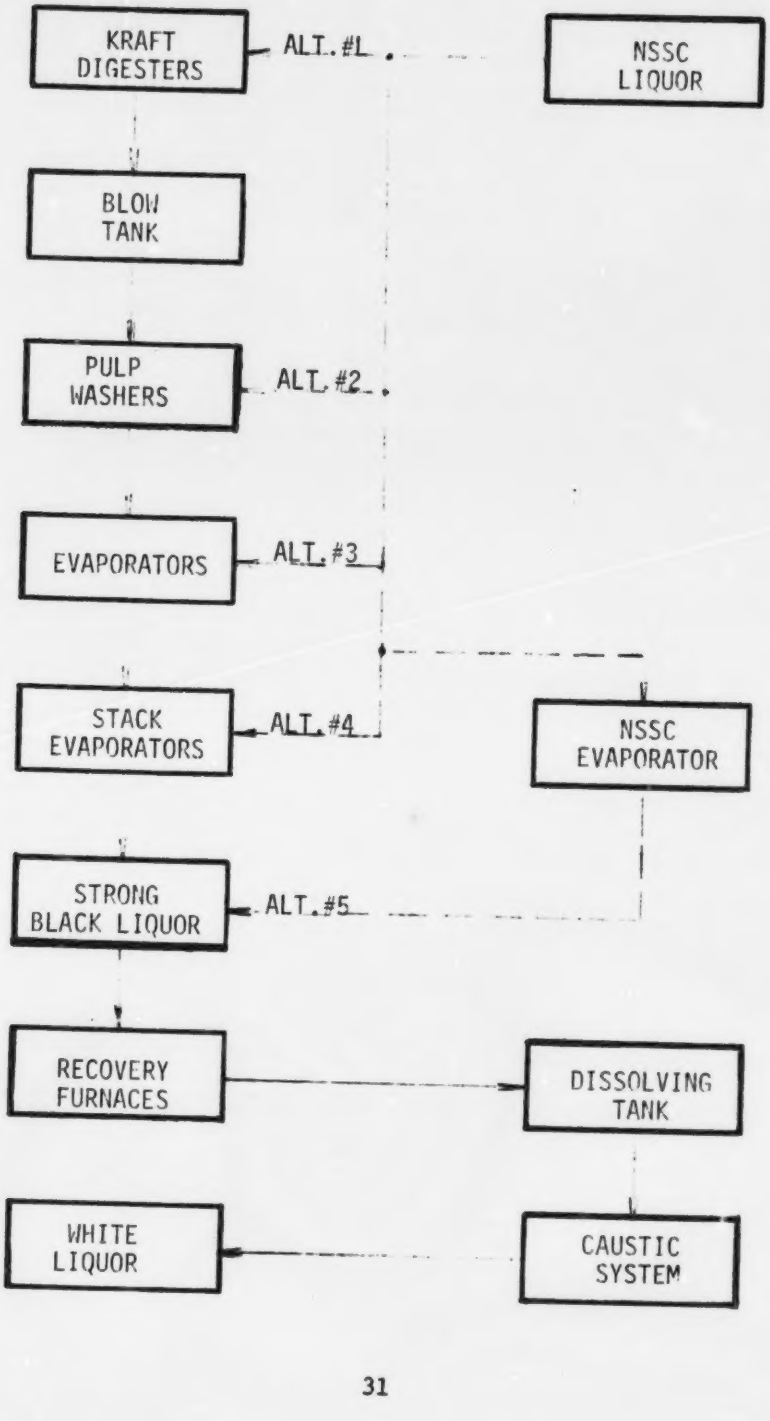
A substantial number of kraft pulp mills have an accessary sodium base neutral sulfite semi-chemical pulp mill. In most instances these are kraft linerboard mills employing pine as a raw material from forest areas where appreciable hardwood species grow as well. These mixed hardwoods are harvested separately but simultaneously with the pine, cooked by the sodium base NSSC process, and manufactured into corrugating board. This product is compatible with linerboard since both are required to produce container board. Such combined pulp production also provides the simplest and most economic means for disposing of the sodium base NSSC spent liquor since it can be introduced into the kraft recovery system at one point or another to provide make-up chemicals to the kraft liquor system. The latter requires elements present in the NSSC liquor, sodium and sulfur, to produce white liquor, the kraft cooking agent. Alternative methods for introducing the spent brown NSSC liquor into the system are illustrated in Figure 7.

Kraft recovery systems can absorb spent liquor from an NSSC mill producing about one-third the tonnage of the kraft operation assuming that adequate evaporator capacity is provided to accept the NSSC brown liquor which is generally more dilute and lower in heat value than the kraft black liquor. One mill has been able to increase this ratio through a process employing crystalization of soda ash from the green liquor for use in preparing NSSC cooking liquor. This limitation has also been overcome by cooking the hardwood with green liquor, although the pulp produced has less desirable characteristics than NSSC. Problems which have been encountered in handling NSSC spent liquor in kraft recovery plants are as follows:

1. Low solids content of NSSC liquor which dilutes kraft black liquor to a degree where considerable additional evaporator capacity and steam is required.
2. Lower heat value of NSSC liquor solids which requires evaporation of combined liquors to a higher consistency making forced feed necessary in the final evaporation effects due to higher liquor viscosity.
3. Increased evaporator fouling and scaling problems and the need for frequent boil-out.
4. Corrosion problems resulting from the presence of NSSC liquor components in the system.

## FIGURE 7

## METHODS EMPLOYED FOR THE INTRODUCTION OF SPENT SODIUM BASE NSSC LIQUOR INTO THE KRAFT RECOVERY SYSTEM


KRAFT DIGESTERS
ALT. #1
NSSC LIQUOR
BLOW TANK
PULP WASHERS
ALT. #2
EVAPORATORS
ALT. #3
STACK EVAPORATORS
ALT. #4
NSSC EVAPORATOR
STRONG BLACK LIQUOR
ALT. #5
RECOVERY FURNACES
DISSOLVING TANK
WHITE LIQUOR
CAUSTIC SYSTEM

5. Interference with the separation of tall oil from the kraft black liquor.
6. The release of hydrogen sulfide on combining the two liquors due to the low pH of the NSSC liquor.

These problems have differed in intensity from mill to mill and have largely been overcome by various means depending upon individual circumstances. Separate evaporation of the brown liquor is practiced at some mills to overcome fouling and scaling as well as tall oil separation difficulties. Introduction of the NSSC liquor as dilution in the kraft digesters has been practiced to reduce evaporation problems. The use of stainless steel evaporator tubes and pH control have been successful in arresting corrosion and hydrogen sulfide release. The practices employed for handling NSSC in kraft systems are fully documented in TAPPI Monograph #32 (16). Details of this practice are also reviewed in standard textbooks on wood pulping (5) (6) (13).

While limitations of 1:3 on the basis of NSSC to kraft pulping may appear severe, this is not usually the case because the large size of modern linerboard mills still allows an economic size NSSC operation.

## Paper Production

Production of paper in unbleached kraft-NSSC mills is similar to the operations as discussed previously for unbleached kraft mills.

## Paperboard from Waste Paper

To convert waste paper to secondary fiber waste paper, sufficient water to provide desired consistency of four to six percent, and chemicals are charged at a controlled rate to a pulper along with steam. In this operation, the paper follows water circulating in a large open vat and is repeatedly exposed to rotating impeller blades. Over a period of time, it is ripped, shredded, and finally defibered (17). The pulper operation may be batch, continuous, or a combination of both. A junker is usually attached which, through centrifugal action, collects and removes extraneous solid materials and papers not suitable for use.

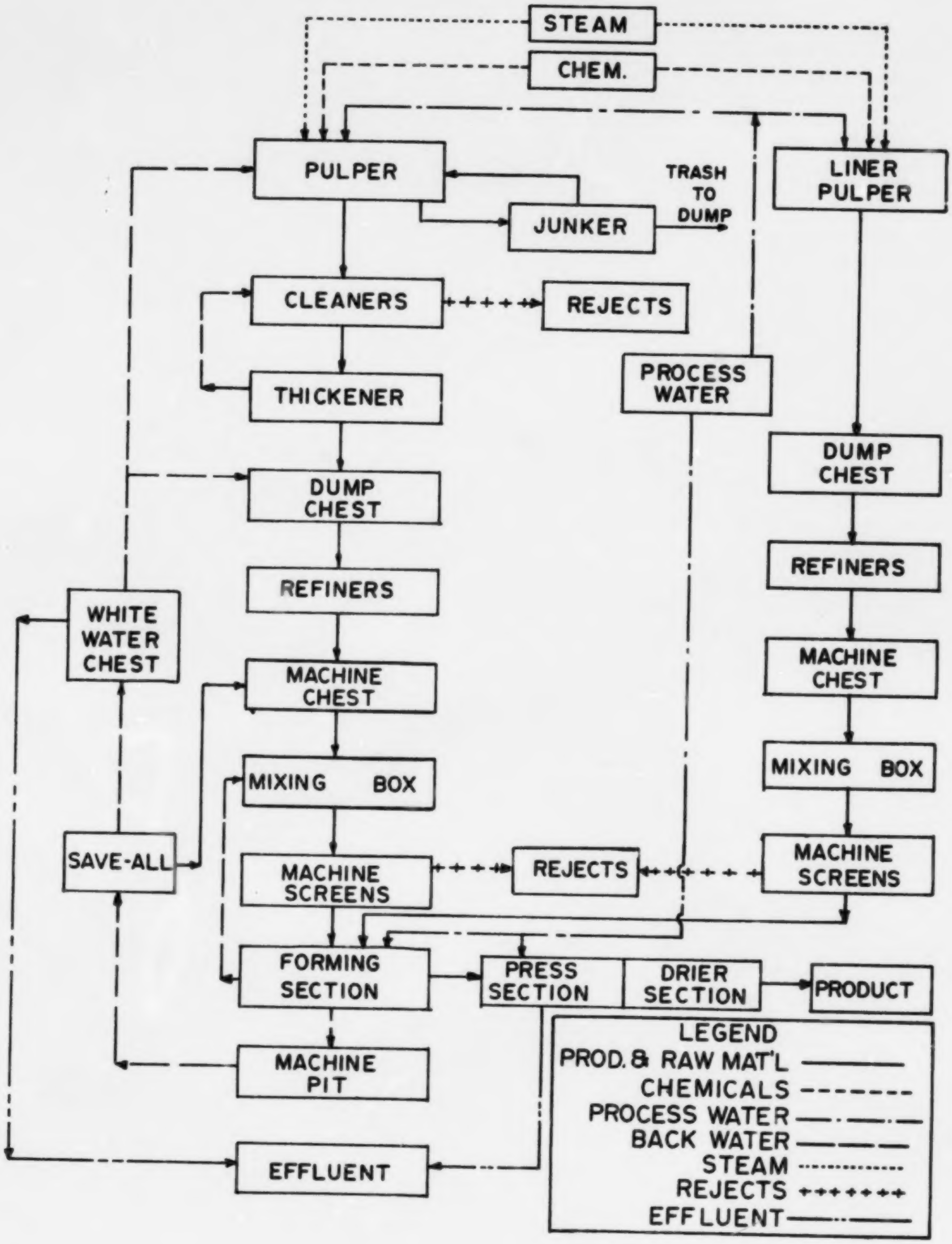
The stock is then passed to centrifugal cleaners, and finally to a thickener which may be preceded by pressure screens. Reject material is dewatered for disposal, and the stock is stored for use or goes directly to the refiners which serve the paper machines.

The removal of modern contaminants found in waste paper, including plastic containers, polystyrene packing material, and other plastic coatings and laminants (17) has required some refinements to the basic process. Some mills also have systems for dispersing the bituminous asphalt found in some reclaimed laminated kraft bags. This type system subjects the fiber to a heat and pressure environment in a press and digester (12).

The paper forming section of the board machine, or wet end, employed depends on the type of product made. Both fourdrinier and cylinder machines and some special devices as well are used (18). Variations and exceptions occur throughout the industry, although in general, a fourdrinier is used to make a single stock sheet and a cylinder machine a multi-ply sheet or heavy board. During recent years, cylinder machines have been replaced by variations of the so-called "dry-vat" principle in order to produce a multi-stock sheet at higher speeds.

A process flow diagram of a typical paperboard from waste paper mill is shown in Figure 8.

FIGURE 8 WASTE PAPER BOARD MILL PROCESS DIAGRAM


STEAM
CHEM.
PULPER
LINER PULPER
TRASH TO DUMP
JUNKER
CLEANERS
REJECTS
THICKENER
PROCESS WATER
DUMP CHEST
DUMP CHEST
REFINERS
REFINERS
WHITE WATER CHEST
MACHINE CHEST
MACHINE CHEST
MIXING BOX
MIXING BOX
SAVE-ALL
MACHINE SCREENS
REJECTS
MACHINE SCREENS
FORMING SECTION
PRESS SECTION
DRIER SECTION
PRODUCT
MACHINE PIT
EFFLUENT
LEGEND
PROD. & RAW MAT'L
CHEMICALS
PROCESS WATER
BACK WATER
STEAM
REJECTS
EFFLUENT

# SECTION IV

## SUBCATEGORIZATION OF THE INDUSTRY

### FACTORS OF CONSIDERATION

This study is concerned with the unbleached kraft, neutral sulfite semi-chemical, and paperboard from waste paper segments of the pulp and paper industry. In order to identify any relevant, discrete subcategories of these segments of the industry, the following factors were considered:

1. Raw materials
2. Production processes
3. Products produced
4. Size and age of mills
5. Waste water characteristics and treatability
6. Geographical location

After analyzing these factors, it was concluded that the pulp and paper segments under study should be divided into the five subcategories listed below:

Unbleached Kraft
Sodium Base Netural Sulfite Semi-Chemical
Ammonia Base Neutral Sulfite Semi-Chemical
Unbleached Kraft - NSSC (Cross Recovery)
Paperboard from Waste Paper

The subcategories are defined as follows:

1. UNBLEACHED KRAFT means the production of pulp without bleaching by a "full cook" process, utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. This pulp is used principally to manufacture linerboard, the smooth facing of "corrugated boxes," but also utilized for other products such as grocery sacks.

2. SODIUM BASE NEUTRAL SULFITE SEMI-CHEMICAL means the production of pulp without bleaching utilizing a neutral sulfite cooking liquor having a sodium base. Mechanical fiberizing follows the cooking stage, and the principal product made from this pulp is the corrugating medium or inner layer in the corrugated box "sandwich."

3. AMMONIA BASE NEUTRAL SULFITE SEMI-CHEMICAL means the production of pulp without bleaching, using a neutral sulfite cooking liquor having an ammonia base. Mechanical fiberizing follows the cooking stage, and the pulp is used to manufacture essentially the same products as is sodium base NSSC.

4. UNBLEACHED KRAFT--NSSC (Cross Recovery) means the production of unbleached kraft and sodium base NSSC pulps in the same mill wherein the

spent NSSC liquor is recovered within the unbleached kraft recovery process. The products made are the same as outlined above for the unbleached kraft and NSSC subcategories, respectively.

5. PAPERBOARD FROM WASTE PAPER means the production of paperboard products from a wide variety of waste papers such as corrugated boxes, box board, and newspapers without doing bleaching, de-inking, or wood pulping operations. Mills which produce paperboard products principally or exclusively from virgin fiber are not included within this subcategory which only covers those mills using waste paper for 80% or more of their fibrous materials.

## RATIONALE FOR SELECTION OF SUBCATEGORIES

The rationale discussed below is supported by raw waste loadings presented in Table 22 in Section V.

### Raw Material

Wood is the primary raw material of all pulping processes. While there are differences in types of wood utilized, such differences have only a minor impact upon waste water characteristics and treatability. For example, assuming normal unit operations, by-product recovery, and in-plant controls, a surveyed mill using southern pine had a raw waste loading $BOD_5$ of 14 kg/kkg (28 lbs/ton) while a similar surveyed mill using western pine had a raw waste loading $BOD_5$ value of 15.5 kg/kkg (31 lbs/ton). This difference is not significant in light of other data from 35 similar mills using many different woods which had a typical $BOD_5$ range of 15 to 20 kg/kkg (30 to 40 lbs/ton).

Raw materials used in the preparation of cooking liquors, however, differ widely among pulping processes. The highly alkaline liquor used in unbleached kraft produces waste water characteristics different from the neutral NSSC liquors, for example. Sodium base NSSC utilizes neutral sodium sulfite cooking liquor as described in Section III. This produces distinctly different waste water characteristics, as shown in Section V, than the unbleached kraft process. Ammonia base NSSC utilizes ammonia as a principal raw material in the preparation of cooking liquor. This produces a waste water high in nitrogen, in contrast to other pulping wastes which are very low in nitrogen, as delineated in Section V.

Paperboard from waste paper does not utilize wood as a raw material and therefore no pulping chemicals are required. Its principal raw material is waste paper. Waste water characteristics from the manufacture of paperboard from waste paper differ widely from those which result from any of the pulping processes. Within the paperboard from waste paper subcategory, many different grades of paper are used for furnish, such as newspapers, magazines, or old corrugated boxes. The different grades of waste paper used as raw stock can have an effect upon the raw waste water characteristics and could be a basis for further subcategorization. However, further subcategorization of mills utilizing waste paper as their only raw material was not feasible because of the following factors: (1) Mills have historically utilized various grades of waste paper as they become available from market conditions depending on product demand and waste paper cost and availability. To further subcategorize within the paperboard from waste paper subcategory based on the type of waste paper could discourage waste paper recycling in that NPDES permits would be issued for a period of years based on the specific type of waste paper being utilized at that time. The resultant effluent limitations in the permits could limit the mills' potential for responding to market waste paper availabilities and product demand. (2) The waste paper utilized as furnish are frequently mixed grades of waste paper. The quantity of a specific grade of waste paper within the mixed grade is generally unknown as mills generally do not keep this information in their records. Thus, data are generally not available to accurately determine the relationship between waste water characteristics and type of furnish. (3) As shown in Tables 48 and 49 in Section VII, paperboard from waste paper mill effluents can be efficiently treated by biological treatment, and quality final effluents can be achieved by biological treatment for a relatively wide range of raw waste characteristics. Therefore, further subcategorization of the paperboard from waste paper subcategory was not justified.

Thus, raw materials produce distinctly different waste water characteristics and were a basis for subcategorization.

## Production Processes

All chemical pulping processes are similar in that each utilizes digestion of wood chips with a chemical cooking liquor and removal of the spent liquor from the cellulose pulp. Process differences among the various pulp types relate primarily to the preparation, use, and recovery of the cooking liquor. In the case of paperboard from waste paper, no pulping is involved.

Pulp or waste paper furnish is used to manufacture paper or paperboard on papermaking equipment which has been described in Section III. The papermaking operation is similar for all products of the subject industry segments. Since the cooking liquors and pulping processes do result in varying waste water characteristics, process differences were used as a basis for subcategorization.

## Products Produced

Section III discusses the wide variety of products produced by these segments of the industry. While the differences in characteristics and end-use of the products are substantial, these differences do not of themselves produce significant variations in waste water characteristics and thus have been considered but not used as a basis to subcategorize the industry segment under study.

Specifically within the paperboard from waste paper subcategory, mills produce both food grade and non-food grade products. The production of food grade products generates larger quantities of waste water and raw waste loads because health considerations preclude the reuse of certain waste waters and reclaimed fiber. The exclusive production of food grade products occurs in very few mills as most mills that produce food grade products from waste paper also produce nonfood grade products. Mill P-18 in Table 21 in Section V produces a combination of grades and at any given time may be producing food grade products on one or two of its machines while making non-food grade on the other. As shown in Table 21, there is a difference between the raw waste characteristics in terms of flow and suspended solids between mill P-18 and, for example, mills P-16 and P-21 which make non-food grades exclusively. However, Table 49 in Section VII reveals that there is little difference in the final effluent in terms of kg/kkg (pounds per ton) of $BOD_5$ and suspended solids. This indicates that both are treatable by primary clarification and biological treatment. In addition, the raw waste characteristics presented in Table 21 in Section V for mill P-23, which is the only mill in the country identified as producing food grade products exclusively, shows relatively high TSS and flow characteristics and average $BOD_5$ levels in comparison to the subcategory averages shown in Table 22 in Section V. As discussed in Section V, mill P-23 possibly could reduce its flow significantly without detriment to the food grade products. Also, effluents from the food grade mill are treatable to levels equivalent to non-food grade mills as shown in Table 49 in Section VII. It should be noted that the data presented in Table 49 for mill P-23 is the effluent from the equivalent of primary treatment. Thus, since it is common practice to produce both food grade and non-food grade at the same mill and because varying raw waste loads can be reduced to acceptable levels in the final effluents by biological treatment, the paperboard from waste paper subcategory was not further subcategorized based on product.

It should be emphasized that mills making food grade products principally or exclusively from virgin fiber are not included in this subcategory. This subcategory covers only those mills using waste paper for 80% or more of their fibrous raw material.

### Age and Size of Mills

There is a substantial variation in age as well as size of mills in the industry. Mills built over 40 years ago are still operating, as well as mills built as recently as 1971. Most, if not all, of the older mills, however, have been substantially upgraded and expanded so that most of them are not "old" in the production sense. Waste water characteristics from the "old" mills do not show significant differences from those of the "new" mills. For example, a surveyed "old" mill built in 1955 but expanded over several years through 1971, had 14 kg/kkg (28 lbs/ton) of production in the raw waste, whereas a "new" mill built in 1971 had an almost identical 14.5 kg/kkg (29 lbs/ton). In the case of ammonia base NSSC mills, age and size are not factors since this is a relatively new process and only two mills are currently operating in the United States.

Even though there is a variation in the size of mills and in raw waste characteristics from these mills, there is no correlation between the size of mills and their raw waste loads. Data on the size of mills and their raw waste loads are presented in Tables 7 and 8 for the unbleached kraft and paperboard from waste paper subcategories, respectively. These two subcategories are presented as examples because they have the largest number of mills within the subcategories for the segments being studied and also have the largest amount of data available for analyses. The data are presented graphically in Figures 9 and 10. Multiple regression analyses of the data showed no correlation between the mills' production and raw waste load.

Thus, the age and size of mills do not justify further subcategorization of the industry segments under study.

### Geographical Location

Waste water characteristics and treatability do not differ significantly with geographical location, irrespective of the raw materials and process employed and the products produced. However, the local climate can affect biological treatment processes as climatic effects can (1) slow biological oxidation processes through lower biological activity due to extremely cold waste water temperatures, and (2) decrease biological treatment efficiencies during the fall and spring when waste water temperatures are changing and also the biological community. These effects can be minimized in the design of the biological treatment systems as described in Section VII. In addition other factors frequently have a greater effect upon final effluent qualities than climate. Also, the effects of climate can be accounted for in the development of effluent limitations by inclusion of mills located in all geographical locations in the data base. Thus, the industry segments were not further subcategorized based upon geographical location or climate.

## TABLE 7

## SIZE VS RAW WASTE CHARACTERISTICS

## UNBLEACHED KRAFT

| Mill | Production kkg/day (tons/day) | BOD5 kg/kkg (lbs/ton) |
|---|---|---|
| UK-21 | 218(240) | 28(56.0) |
| UK-11 | 346(382) | 19.9(39.9) |
| UK-23 | 372(410) | 37(74.0) |
| UK-13 | 453(500) | 12(24.0) |
| UK-19 | 499(550) | 23.5(47.0) |
| UK-20 | 544(600) | 24(48.0) |
| UK-18 | 635(700) | 18(36.0) |
| UK- 7 | 641(707) | 12.5(25.0) |
| UK- 6 | 732(807) | 21.2(42.5) |
| UK- 4 | 751(828) | 15.5(31.0) |
| UK- 3 | 794(875) | 14(28.0) |
| UK-14 | 816(900) | 13(26.0) |
| UK-17 | 816(900) | 17.8(35.7) |
| UK-24 | 816(900) | 58(116.0) |
| UK- 2 | 824(909) | 12.2(24.5) |
| UK-16 | 939(1035) | 15(30.0) |
| UK-12 | 952(1050) | 9(18.0) |
| UK- 8 | 997(1099) | 19(38.0) |
| UK- 1 | 1020(1125) | 13.5(27.0) |
| UK- 5 | 1201(1324) | 19(38.0) |
| UK- 9 | 1376(1517) | 17.2(34.5) |
| UK-15 | 1451(1600) | 15(30.0) |
| UK-10 | 1464(1614) | - - |
| UK-22 | 1696(1870) | 35(70.0) |

## TABLE 8

## SIZE VS RAW WASTE CHARACTERISTICS

## PAPERBOARD FROM WASTE PAPER

| Mill | Production kkg/day (tons/day) | BOD5 kg/kkg (lbs/ton) |
|---|---|---|
| P- 8 | 50(55) | 15(30) |
| P-19 | 56(62) | 4( 8) |
| P-12 | 63(70) | 13(26) |
| P-23 | 73(80) | 12.5(25) |
| P- 2 | 89(98) | 15(30) |
| P- 1 | 91(100) | 7.5(15) |
| P-20 | 91(100) | 7.5(15) |
| P-22 | 91(100) | 9(18) |
| P-10 | 91(100) | 10(20) |
| P-11 | 91(100) | 18.5(37) |
| P- 4 | 114(126) | 12(24) |
| P- 9 | 136(150) | 12.5(25) |
| P-21 | 145(160) | 9.5(19) |
| P-15 | 145(160) | 16.3(32.5) |
| P- 5 | 154(170) | 13.5(27) |
| P- 3 | 163(180) | 12(24) |
| P-14 | 181(200) | 20(40) |
| P- 7 | 185(204) | 5.5(11) |
| P- 6 | 190(210) | 7(14) |
| P-18 | 245(270) | 5.5(11) |
| P-16 | 272(300) | 10(20) |
| P-13 | 272(300) | 16.5(33) |
| P-17 | 440(485) | 6(12) |

FIGURE 9

**RAW WASTE CHARACTERISTICS vs SIZE OF MILL**
**UNBLEACHED KRAFT**

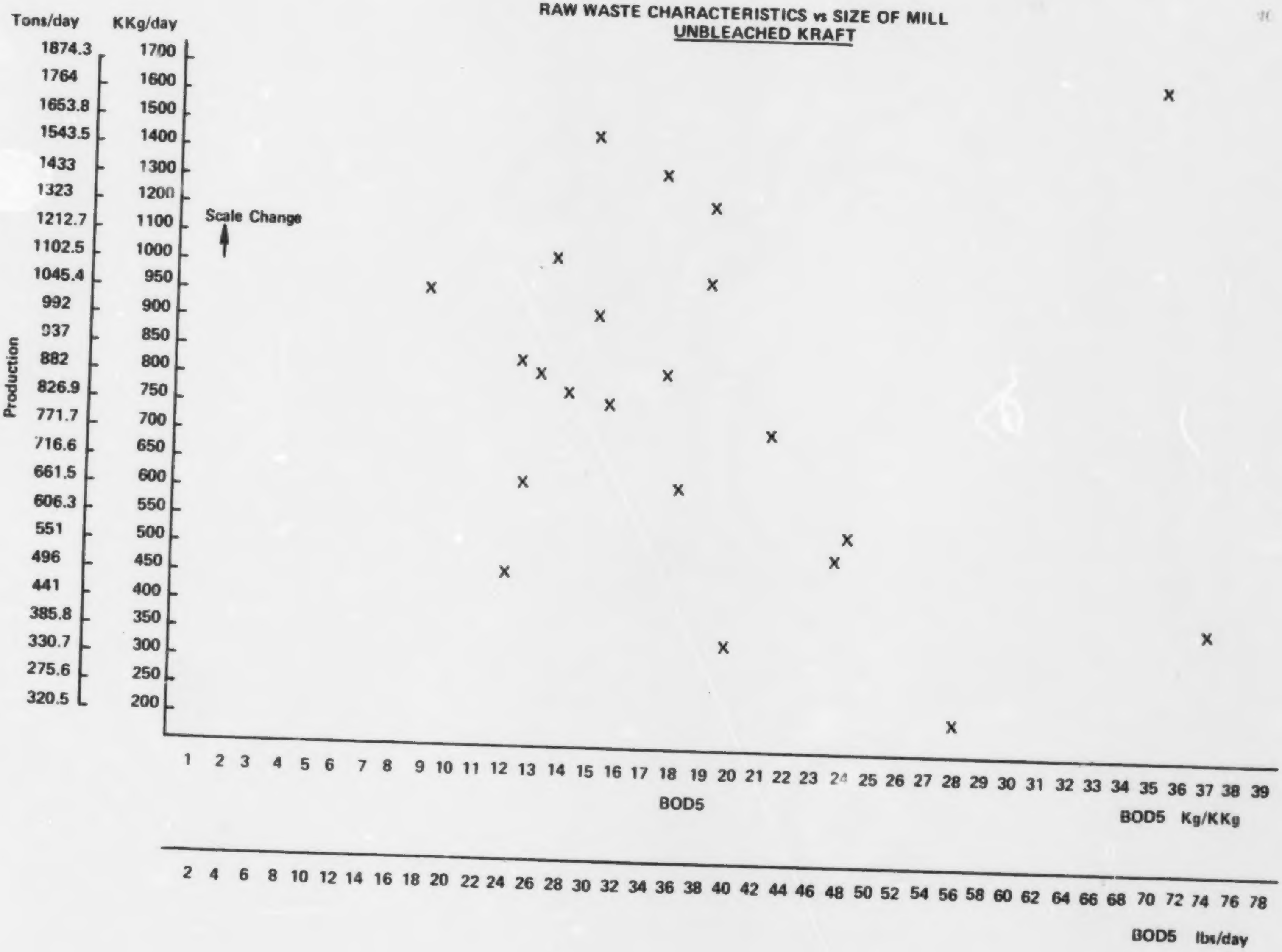
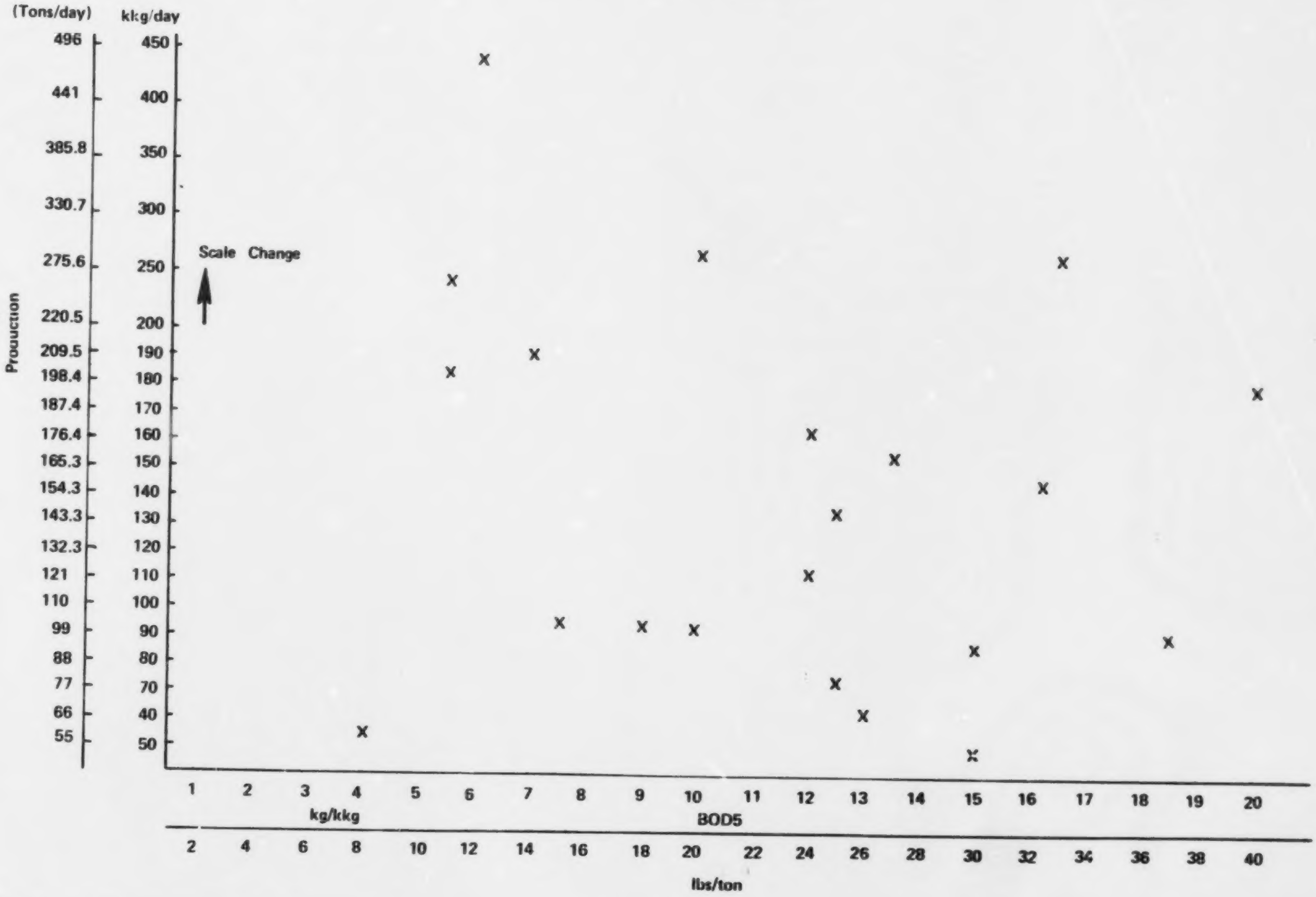


FIGURE 10

RAW WASTE CHARACTERISTICS vs SIZE OF MILL

PAPERBOARD FROM WASTE PAPER



## SECTION V

## WATER USE AND WASTE CHARACTERIZATION

Usage of water and resultant waste water characteristics for the general operations of (1) wood preparation, (2) pulping processes, and (3) the paper machine are discussed in this section. Since a relatively thorough discussion of wood preparation is presented, it should be noted that raw waste loads resulting from wood preparation are much less than loads resulting from pulping processes and paper production, and usually wood preparation operations utilize waste water from another unit within the mill. In addition, waste water characteristics are reported in this section as averages for the amount of data available unless otherwise noted.

### WOOD PREPARATION

Wood, the primary fiber raw material for unbleached kraft and NSSC pulps, is received at the mills in various forms and consequently must be handled in a number of different ways (6). Some mills receive chips from saw mills or barked logs which can be chipped directly. In these instances, little, if any, water is employed in preparation of the wood and no effluent is produced. Most mills receive roundwood in short lengths with the bark remaining on it, and, since the bark interferes with the pulping process and product quality, it must be removed.

Logs are frequently washed before dry or wet barking in order to remove silt ( 19 ). In most installations a water shower is activated by the log itself while on the conveyer so that a minimum of water is used. The actual quantity discharged per unit of wood handled or pulp produced is most difficult to ascertain because of the wide weight variation in stick size and the fact that not all the wood barked at some installations is pulped, a portion going to lumber.

It is established that this effluent is very low in color and $BOD_5$ (20) and that its suspended solids content is largely silt. Hence, it is generally disposed of on the land together with grits and dregs from the pulp mill or ashes from the boiler plants, or combined with the general flowage to the treatment works. Most of the pulpwood used in the United States is small in diameter and is barked dry in drums. However, when large diameter or long wood is used, wet barking is commonly employed. The latter operation is pretty much limited to northern mills and its use is presently declining.

Wet barking of logs is accomplished by one of three methods: by drums, pocket barkers, or hydraulic barkers (6)(21). Slabs are generally handled by hydraulic units as is the larger diameter and long roundwood. The wet drum barker consists of a slotted drum equipped with internal

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staves which knock the bark from the wood as the drum rotates in a pool of water. The bark falls through the slots and is removed with the overflow of water. These units handle from 7 to 45 cords of wood daily. Frequently the water supplied to them is spent process water, and recycling within the barking unit itself is often practiced. Barkers of this type contribute BOD$_5$ from 7.5 to 10 kilograms per metric ton (15-20 lbs/short ton) of wood barked, and from 15 to 20 kilograms per metric ton (30-40 lbs/short ton) of suspended solids. Examples of the BOD$_5$ and suspended solids concentration of this waste water with the barkers using fresh process water are shown in Table 9.

Wet pocket barkers are stationary machines which abrade bark from timber by jostling and gradually rotating a confined wood stack against an endless chainbelt equipped with projections called "dogs" which raise the wood pile allowing bark to pass between the chains. Water is sprayed through apertures in the side of the pocket at rates of between 1254 and 2280 liters per minute (330 and 600 gpm) for pockets of 2.8 and 5.7 cords per hours, respectively. The use of this process is rapidly declining in the United States. Hydraulic barkers employ high-pressure water jets to blow the bark from the timber which is either conveyed past them or rotated under a moving jet which traverses the log. The volume of water employed is generally from 19,000 to 45,600 liters (5000 to 12,000 gallons) per cord of wood barked depending upon log diameter.

Water discharged from all three types of wet barking is generally combined with log wash water, and then coarse screens are used to remove the large pieces of bark and wood slivers which are conveyed away continuously. The flowage then passes to fine screens. These are of the drum, fixed vertical, or horizontal vibrating type, having wire mesh or perforated plate media with openings in the range of 0.127 to 0.254 centimeters (0.05 to 0.10 inches). Screenings are removed and mixed with the coarse materials from the initial screenings, the mixture being dewatered in a press prior to burning in the bark boiler. Press water, which is combined with the fine screen effluent, is very minor in volume. The total waste flow, which amounts to about 19,000 to 26,600 liters (5,000 to 7,000 gallons) a cord, generally carries from 0.5 to 5.0 kg/kkg (1.0 to 10 lbs/ton) of BOD$_5$ and from 3.0 to 27.5 kg/kkg (6.0 to 55 lbs/ton) of TSS.

## TABLE 9

## ANALYSIS OF WET DRUM BARKING EFFLUENTS*

| MILL | TOTAL SUSPENDED SOLIDS mg/l | %ASH mg/l | BOD$_5$ mg/l | COLOR APHA UNITS |
|---|---|---|---|---|
| L-12 | 2017 | -- | 480 | 20 |
| L-13 | 3171 | 21 | 605 | 50 |
| L-14 | 2875 | 18 | 987 | 50 |

*The water source for wet drum barkers is frequently a waste water which has been recycled from some other source.

The combined discharge contains bark fines and silt, the latter varying greatly in quantity since its presence is due mainly to soil adhering to the logs. In dry weather the percentage of silt in relation to bark fines is low as is the case when logs are stored in or transported by water. However, attachment of mud in wet weather can make this material a major percentage of the total suspended matter passing the fine screens.

Fine screen effluent following hydraulic barkers has been analyzed by several investigators ( 22 ) ( 23 ) ( 24 ), and examples are shown in Table 10. It can be concluded from the data included in these publications that these effluents have a total suspended solids content ranging from 521 to 2350 mg/l with the ash content running from 11 to 27 percent. The latter is generally below 15 percent for clean logs. $BOD_5$ values range between 56 and 250 mg/l. These low values are due to the fact that the contact of the water with the bark is short and no grinding action on the wood takes place. Hence, leaching of wood and bark solubles is minimized. The water originally employed is all fresh process water, since the close clearances of the high pressure pumping systems supplying water to the jets will not tolerate the presence of suspended solids in the water.

Such low values are not the case with drum and pocket grinding where attrition in contact with water over an appreciable period of time takes place. Also, spent pulping process waters already high in $BOD_5$ and color are sometimes used for these barking processes which raise further the ultimate level of organics in the screened effluent. While wet drum and pocket barker fine screen discharge is not greatly different from that of hydraulic barkers in suspended solids content, the $BOD_5$ can be considerably higher ( 20 ) ( 22 ).

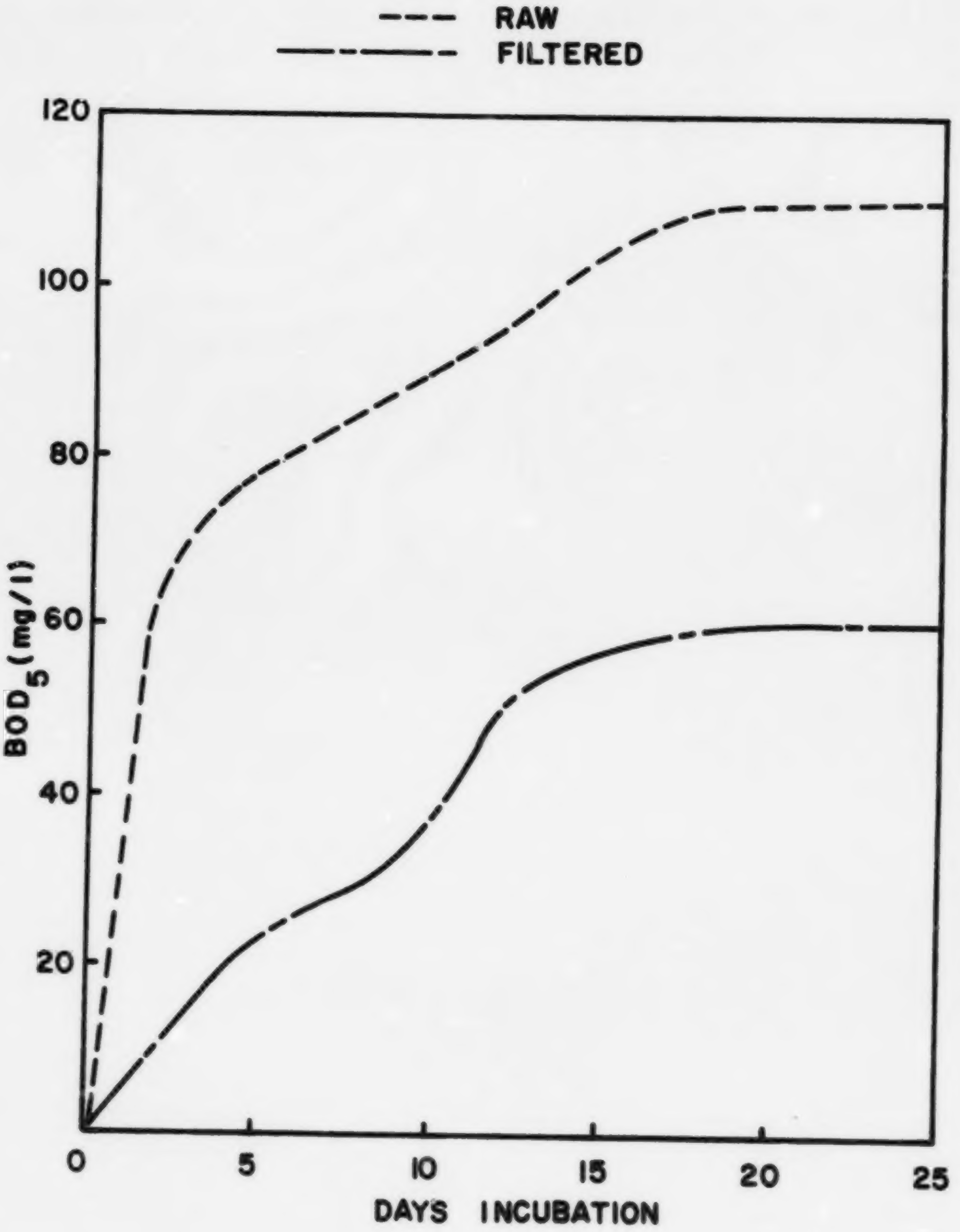
$BOD_5$ values are also greatly affected by the species of wood barked and the season in which the wood was cut since wood juices and water extractables are responsible for it. The $BOD_5$ contributed by the suspended matter present is a minor fraction of the total $BOD_5$. The curves presented in Figure 11, indicate that the 15-day values are about twice those of the five day with little further demand exerted after this period (23). Table 11 illustrates sewer losses from wet barking operations, while Figure 12 shows settleability characteristics of barker screening effluent.

# TABLE 10

## ANALYSIS OF HYDRAULIC BARKING EFFLUENTS

| MILL | TOTAL SUSPENDED SOLIDS mg/1 | % ASH mg/1 | BOD5 | COLOR APHA UNITS |
|---|---|---|---|---|
| L-11 | 2362 | 27 | 585 | 50 |
| L-22 | 889 | 14 | 101 | 50 |
| L-33 | 1391 | 17 | 64 | 50 |
| L-44 | 550 | 11 | 99 | 50 |
| L-55 | 521 | 13 | 121 | 50 |
| L-66 | 2017 | 21 | 56 | 50 |
| L-77 | 2000 | 19 | 97 | -- |
| L-88 | 600 | 10 | 250 | 35 |

FIGURE 11
LONG TERM BOD OF BARKER EFFLUENT
( AFTER FINE SCREENS )



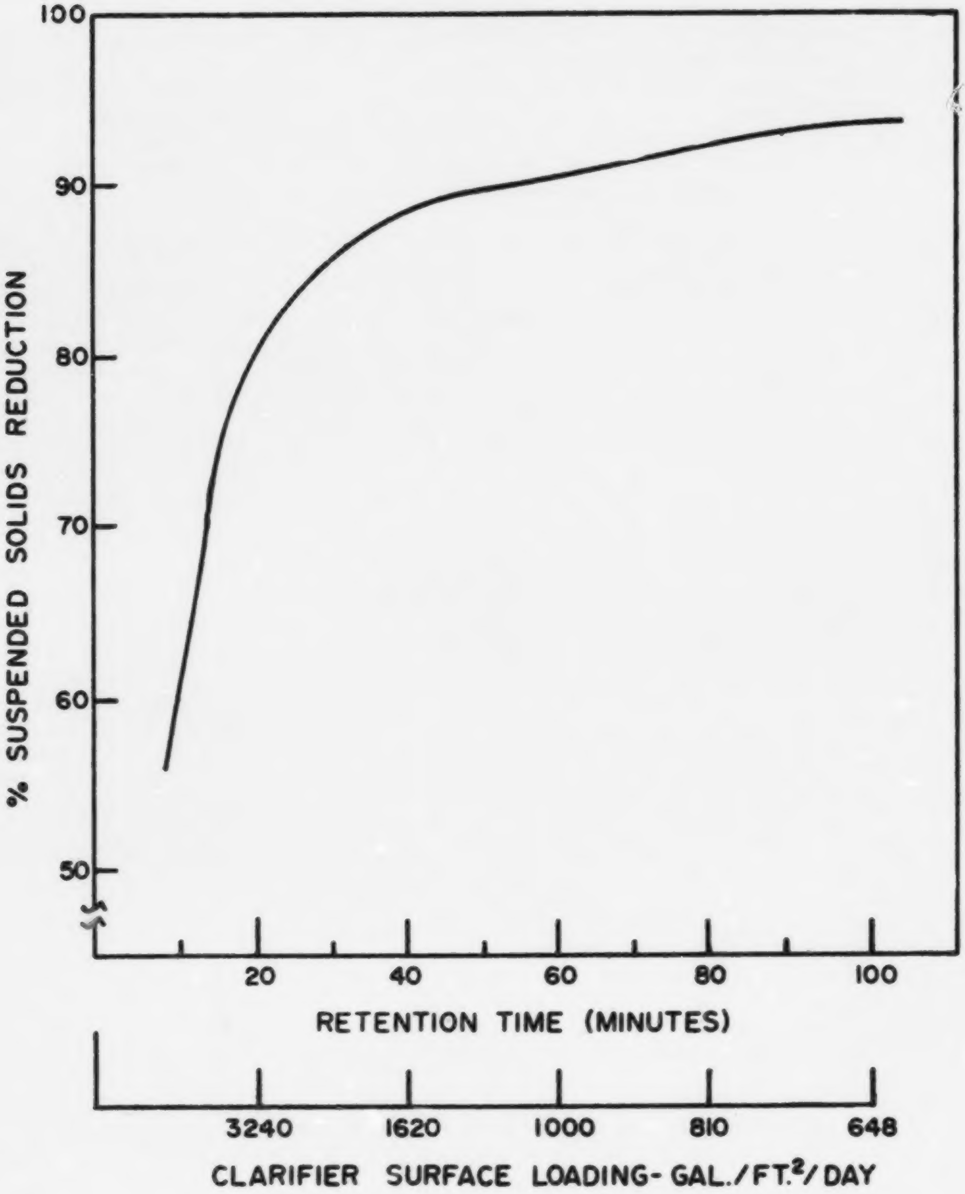
## TABLE 11

## SEWER LOSSES FROM WET BARKING OPERATIONS

| Mill | Effluent Volume Kiloliter/kkg (1000 gal/ton) | BOD5 kg/kkg (lbs/ton) | TSS kg/kkg (lbs/ton) |
|---|---|---|---|
| L-1 | 11.3 (2.7) | 0.6 (1.2) | 3.2 (6.4) |
| L-2 | 10.0 (2.4) | 0.9 (1.8) | 3.8 (7.6) |
| L-3 | 14.6 (3.5) | 6.0 (12.0) | 2.75 (5.5) |
| L-4 | 25.0 (6.0) | 3.0 (6.0) | 15.0 (30.0) |
| L-5 | 12.5 (3.0) | 1.25 (2.5) | 11.4 (22.8) |
| L-6 | 4.2 (1.0) | 1.0 (2.0) | 5.0 (10.0) |
| L-7 | 23.4 (5.6) | 9.5 (19.0) | 9.0 (18.0) |
| L-8 | 4.2 (1.0) | 5.75 (11.5) | 15.0 (30.0) |
| L-9 | 31.3 (7.5) | 11.05 (20.1) | 17.0 (34.0) |

FIGURE 12

SETTLING RATE OF
BARKER SCREENING EFFLUENT



## PULPING PROCESS

A summary of raw waste characteristics for each of the subcategories is presented in Table 22 at the end of this section.

### Unbleached Kraft

The waste water resulting from unbleached kraft pumping comes primarily from three areas of the process. The effluent from pulp washing, which separates the spent liquor from the pulp, formerly consisted mainly of decker filtrate water containing spent cooking liquor solids and accounts for a high percentage of the total effluent. Today, the use of hot stock washing, as discussed in Section VII, has considerably reduced the waste load generated in the washing operation.

Relationships between solids concentration of this waste water and BOD5, light absorbence, and conductivity are shown in Figure 13 ( 25 ). It should be noted that the relationships shown in Figure 13 will vary somewhat depending upon the specific case. The relationship of dissolved solids to the three other parameters of waste strength is linear and of very similar slope. From this it can be concluded that effluent strength as measured by these parameters is a direct function of pulp washing efficiency and that conductivity can be employed as an accurate monitoring index for the pulp washing operation. The magnitude of this relationship can be disturbed somewhat by loss of liquor to the vacuum system or to floor drains due to foaming on the washers.

The second area of waste water sources is condensate streams. Relief condensate from the digesters is condensed and the turpentine is recovered from it by decantation. The residual water from this operation is sewered. Blow and evaporation condensates are contaminated mainly with methanol, ethanol, and acetone, with the extent of their content a function of the wood species pulped ( 26 ). When surface condensers are employed on the evaporators, the volume of this stream is low and its BOD5 can be reduced by air stripping in a cooling tower (27) or by steam stripping ( 28 ). These condensates are frequently reused for pulp washing.

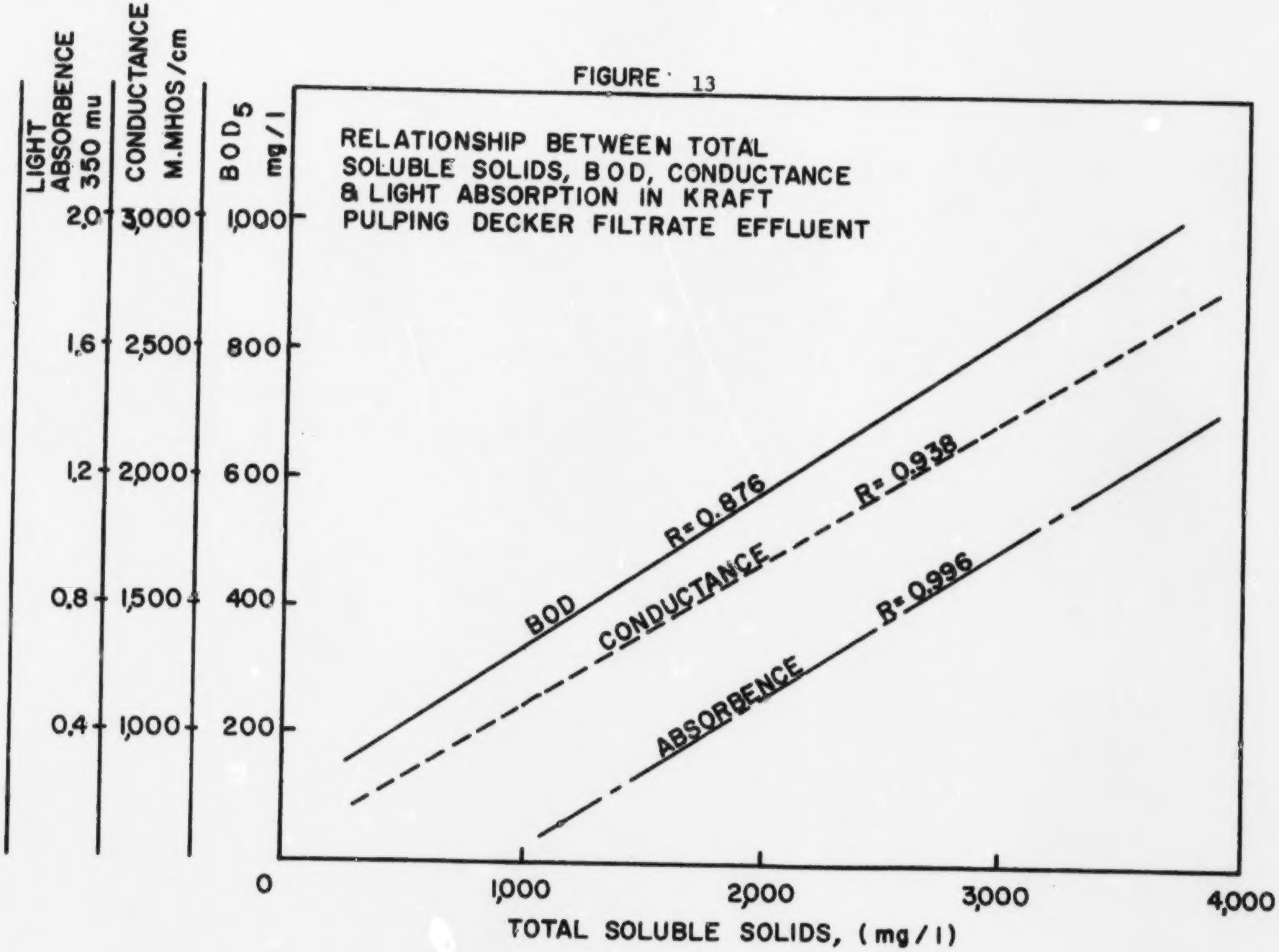
All chemical recovery operations and other minor losses constitute the last BOD5 source from kraft pulping.

Losses per unit of production from kraft pulping itself are difficult to determine because of the common practice of reusing water from integrated papermaking operations into the pulp mill ( 29 ).

A process flow and materials diagram for a 907 metric ton (1000 short ton) a day kraft linerboard mill is shown in Figure 14.

As shown in Tables 12 and 13, total BOD5 raw waste load from unbleached kraft mills, including both pulping and papermaking operations, is

FIGURE 13



RELATIONSHIP BETWEEN TOTAL SOLUBLE SOLIDS, BOD, CONDUCTANCE & LIGHT ABSORPTION IN KRAFT PULPING DECKER FILTRATE EFFLUENT

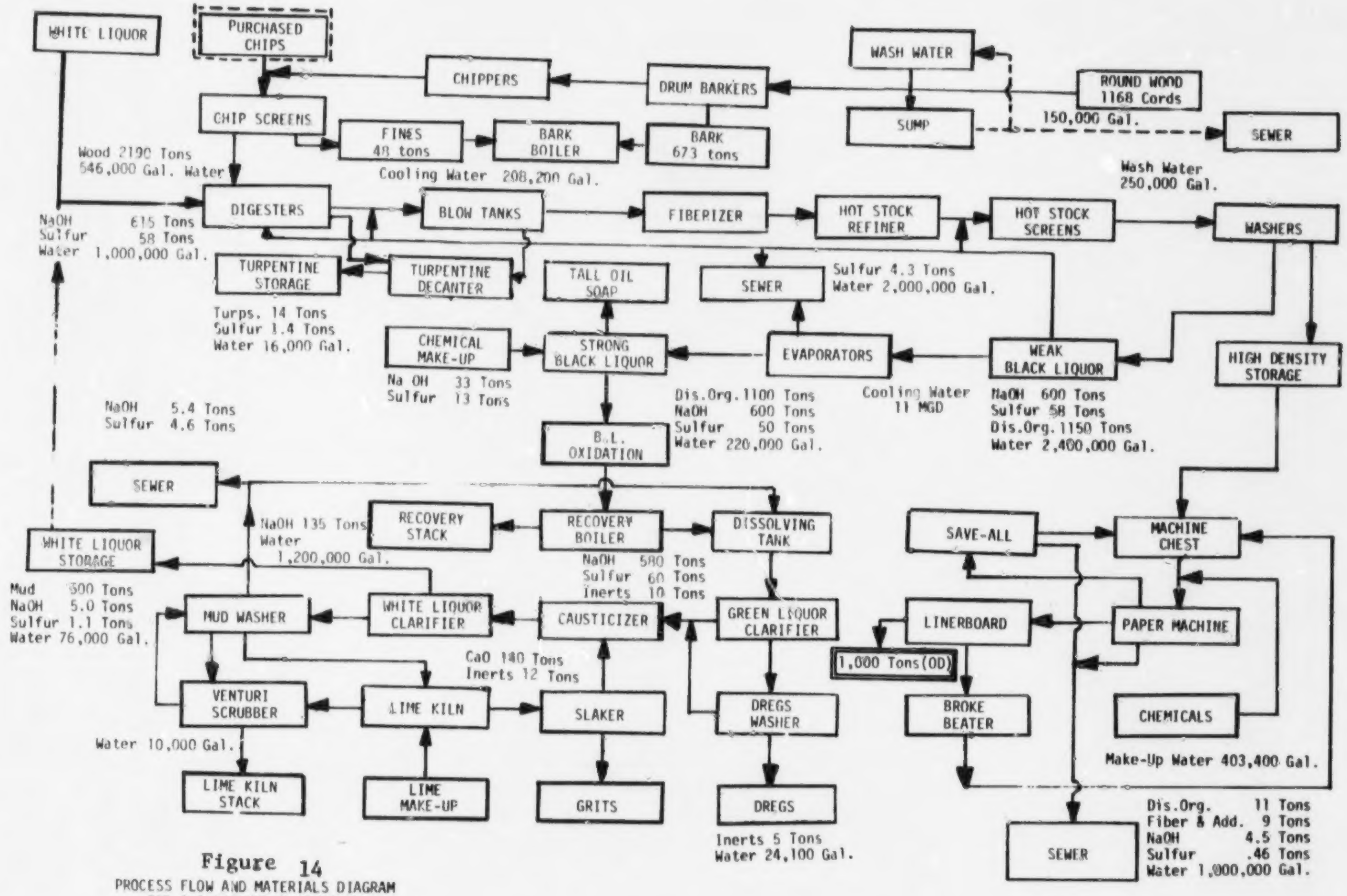

WHITE LIQUOR
PURCHASED CHIPS
CHIPPERS
DRUM BARKERS
WASH WATER
ROUND WOOD 1168 Cords
CHIP SCREENS
FINES 48 tons
BARK BOILER
BARK 673 tons
SUMP
150,000 Gal.
SEWER
Wash Water 250,000 Gal.
Wood 2190 Tons
546,000 Gal. Water
Cooling Water 208,200 Gal.
DIGESTERS
BLOW TANKS
FIBERIZER
HOT STOCK REFINER
HOT STOCK SCREENS
WASHERS
NaOH 615 Tons
Sulfur 58 Tons
Water 1,000,000 Gal.
TURPENTINE STORAGE
TURPENTINE DECANTER
TALL OIL SOAP
SEWER
Sulfur 4.3 Tons
Water 2,000,000 Gal.
Turps. 14 Tons
Sulfur 1.4 Tons
Water 16,000 Gal.
CHEMICAL MAKE-UP
STRONG BLACK LIQUOR
EVAPORATORS
WEAK BLACK LIQUOR
HIGH DENSITY STORAGE
Na OH 33 Tons
Sulfur 13 Tons
Dis.Org. 1100 Tons
NaOH 600 Tons
Sulfur 50 Tons
Water 220,000 Gal.
Cooling Water 11 MGD
NaOH 600 Tons
Sulfur 58 Tons
Dis.Org. 1150 Tons
Water 2,400,000 Gal.
NaOH 5.4 Tons
Sulfur 4.6 Tons
B.L. OXIDATION
SEWER
RECOVERY STACK
RECOVERY BOILER
DISSOLVING TANK
SAVE-ALL
MACHINE CHEST
NaOH 135 Tons
Water 1,200,000 Gal.
WHITE LIQUOR STORAGE
NaOH 580 Tons
Sulfur 60 Tons
Inerts 10 Tons
Mud 300 Tons
NaOH 5.0 Tons
Sulfur 1.1 Tons
Water 76,000 Gal.
MUD WASHER
WHITE LIQUOR CLARIFIER
CAUSTICIZER
GREEN LIQUOR CLARIFIER
LINERBOARD
PAPER MACHINE
1,000 Tons(OD)
CaO 140 Tons
Inerts 12 Tons
VENTURI SCRUBBER
LIME KILN
SLAKER
DREGS WASHER
BROKE BEATER
CHEMICALS
Water 10,000 Gal.
Make-Up Water 403,400 Gal.
LIME KILN STACK
LIME MAKE-UP
GRITS
DREGS
SEWER
Inerts 5 Tons
Water 24,100 Gal.
Dis.Org. 11 Tons
Fiber & Add. 9 Tons
NaOH 4.5 Tons
Sulfur .46 Tons
Water 1,000,000 Gal.

**Figure 14**
PROCESS FLOW AND MATERIALS DIAGRAM FOR A 1,000 TON A DAY KRAFT LINERBOARD MILL

# TABLE 12

## RAW WASTE CHARACTERISTICS

## UNBLEACHED KRAFT

| Mill | FLOW kiloliters/kkg (1000 gal/ton) | BOD5 kg/kkg (lbs/ton) | TSS* kg/kkg (lbs/ton) |
|---|---|---|---|
| L-UK 1 | 108.4(26) | 21(42) | 15(30) |
| L-UK 2 | 41.7(10) | 11(22) | 20(40) |
| L-UK 3 | 79.2(19) | 19(38) | 6(12) |
| L-UK 4 | 12.5( 3) | 17.5(35) | 9.5(19) |
| L-UK 5 | 50.1(12) | 16.5(33) | 12.5(25) |
| L-UK 6 | 125.1(30) | 45(90) | 11.5(23) |
| L-UK 7 | 62.6(15) | 9(18) | 34.5(69) |
| L-UK 8 | 25( 6) | 15(30) | 6(12) |
| L-UK 9 | 50(12) | 13(26) | 15(30) |
| L-UK 10 | 112.6(27) | 20.5(41) | 26.5(53) |
| L-UK 11 | 50(12) | 13.5(27) | 27.5(55) |
| L-UK 12 | 41.7(10) | 50.5(101) | 69.5(139) |
| L-UK 13 | 66.7(16) | 16.5(33) | -( - ) |
| L-UK 14 | 37.5( 9) | 17(34) | 13.5(27) |

*: Analytical Technique unknown.

Note: Mills L-UK 1 through L-UK 14 are from the literature and thus no identification is possible.

TABLE 13

RAW WASTE CHARACTERISTICS

UNBLEACHED KRAFT

| Mill | FLOW kiloliters/kkg (1000 gal/ton) | BOD5 kg/kkg (lbs/ton) | TSS kg/kkg (lbs/ton) |
|---|---|---|---|
| UK-1 | 39.2 ( 9.4) | 13.5 (27.0) | 10.5 (21)* |
| UK-2 | 50 (12.0) | 12.2 (24.5) | 18.7 (37.5)* |
| UK-3 | 39.6 ( 9.5) | 14 (28.0) | 28 (56) |
| UK-4 | 85.5 (20.5) | 15.5 (31.0) | 19.5 (39) |
| UK-5 | 60 (14.4) | 19 (38.0) | 19.5 (39) |
| UK-6 | 64.2 (15.4) | 21.2 (42.5) | 23.3 (46.6) |
| UK-7 | 112.6 (27.0) | 12.5 (25.0) | - |
| UK-8 | 43.4 (10.4) | 19 (38.0) | - |
| UK-9 | 43.4 (10.4) | 17.2 (34.5) | 11.6 (23.2)* |
| UK-10 | 55.5 (13.3) | - | - |
| UK-11 | 43.8 (10.5) | 19.9 (39.9) | 19.1 (38.1) |
| UK-12 | - | 9 (18.0) | - |
| UK-13 | - | 12 (24.0) | - |
| UK-14 | - | 13 (26.0) | - |
| UK-15 | - | 15 (30.0) | - |
| UK-16 | - | 15 (30.0) | - |
| UK-17 | - | 17.8 (35.7) | - |
| UK-18 | - | 18 (36.0) | - |
| UK-19 | - | 23.5 (47.0) | - |
| UK-20 | - | 24 (48.0) | - |
| UK-21 | - | 28 (56.0) | - |
| UK-22 | - | 35 (70.0) | - |
| UK-23 | - | 37 (74.0) | - |
| UK-24 | - | 58 (116.0) | - |

*NSM

Note: Data for mills UK-1 through UK-11 are from mill records of daily discharge data over one year's time. Data for mills UK-12 through UK-24 are from mill reports to the NCASI of annual average waste loads.

typically in the 12 to 20 kilograms per metric ton (24 to 40 lbs/ton) range. The average raw waste $BOD_5$ load for mills in Table 12 was 16.4 kg/kkg (32.8 lbs/ton) with a range of 11 to 21 kg/kkg (22 to 42 lbs/ton) (not including mills L-UK-6, L-UK-7, and L-UK-12, inclusion of which would disproportionately affect the average). The average raw waste load for mills in Table 13 was 16.9 kg/kkg (33.8 lbs/ton) with a range of 12 to 28 kg/kkg (24 to 56 lbs/ton) (not including mills UK-12, UK-22, UK-23, and Uk-24, inclusion of which would disproportionately affect the average). The average $BOD_5$ raw waste load for mills UK-1 through UK-11 in Table 13, for which daily data over one year's time was available was 16.4 kg/kkg (32.8 lbs/ton) with a range of 12.25 to 21.25 kg/kkg (24.5 to 42.5 lbs/ton). The data presented in Table 13 is more recent data than the data in Table 12, and it should be pointed out that the mills in Table 12 may be included in Table 13 since identification of the mills was not available.

The total suspended solids raw waste load for unbleached kraft mills are generally reported to be within a range of 10 to 15 kg/kkg (20 to 30 lbs/ton). The mills in Table 12 average 15 kg/kkg (30 lbs/ton) with a range of 6 to 27.5 kg/kkg (12 to 55 lbs/ton) (not including UK-6, UK-7, and UK-12). However, the technique utilized for TSS analysis is unknown for mills in Table 12. The mills using SM in Table 13 average 21.9 kg/kkg (43.8 lbs/ton) with a range of 19 to 28 kg/kkg (38 to 56 lbs/ton), but data resulting from SM was available for only five of the 24 mills listed. Raw waste color APHA color units (CU) are typically in the 500-1500 range, and one of the surveyed mills fell in the low end of this range at 567 units, while a second surveyed mill, on a short term test, measured 286 color units.

The impact of inplant measures to reduce raw waste loads and flow is evident in the flow data presented in Tables 12 and 13. The flows averaged 57,550 liters/kkg (13,800 gal/ton) for the mills in Table 12 (not including L-UK-6, L-UK-7, and L-UK-12). The average flow in Table 13 was 52,550 liters/kkg (12,600 gal/ton) with a range from 39,200 to 85,480 liters/kkg (9,400 to 20,500 gal/ton) for mills UK-1 through UK-11 (except mill UK-7, inclusion would disproportionately affect the average). In 1966, 19 unbleached kraft mills were reported (29) to have a median water usage of 121,017 liters/kkg (29,000 gal/ton). The details of methods utilized to accomplish this flow reduction, with concomitant reductions in pollution levels in the raw waste, are described in Section VII.

## Sodium Base Neutral Sulfite Semi-chemical

In most sodium base NSSC mills, liquor is prepared by burning sulfur and absorbing it in soda ash or ammonia, depending on base utilized. This part of the process produces only small quantities of liquid wastes other than floor drainings, equipment wash-up, and cooling waters which can frequently be used as process water.

Digester-relief and blow gases are condensed, and in some mills the condensate is used for pulp washing. Pulp wash water together with drainings from the blow tank are delivered to the recovery or liquor burning system, or in the case of some sodium base mills to an adjunct kraft recovery system.

From the washers the pulp is conveyed to an agitated chest where it is diluted with white water from the paper mill to the desired consistency for feed to the secondary refiners serving the papermaking operation. Other than spent liquor, the pulping and washing operations discharge little waste water since the small amount of residual liquor solids present in pulp is carried through the machine system passing out with the overflow white water.

The final effluent from sodium base NSSC mills is relatively low in volume because of the high degree of recycle commonly practiced in both the pulping and papermaking operations. For the same reason it is high in $BOD_5$. Without recovery or incineration of the liquor, effluents would range from 1500 to 5000 mg/l with a suspended solids content of from 400 to 600 mg/l. The color and chemical oxygen demand (COD) content would be correspondingly high ( 30 ). Overall process losses in $BOD_5$ and total suspended solids without recovery in relation to pulp yield are shown in Figures 15 and 16, respectively.

As described briefly above, the raw waste load from NSSC mills is dependent upon several factors including water use, cooking liquor disposal or recovery, and the amount of waste paper used as furnish. Many mills utilize old corrugated boxes or corrugated box clippings as a portion of their furnish. The raw waste load per ton of pulp furnish is much different for furnish from old corrugated than that from NSSC pulps and has been reported to be approximately 10 kg $BOD_5$ per kkg of pulp (20 lbs $BOD_5$ per ton of pulp). The $BOD_5$ is generally a result of the solubilization of the starch used as a binder in corrugated board and by the residual $BOD_5$ left in the corrugated box from the original kraft and NSSC processes (31).

FIGURE 15

BOD LOAD OF NSSC PULPING

(WITHOUT RECOVERY)

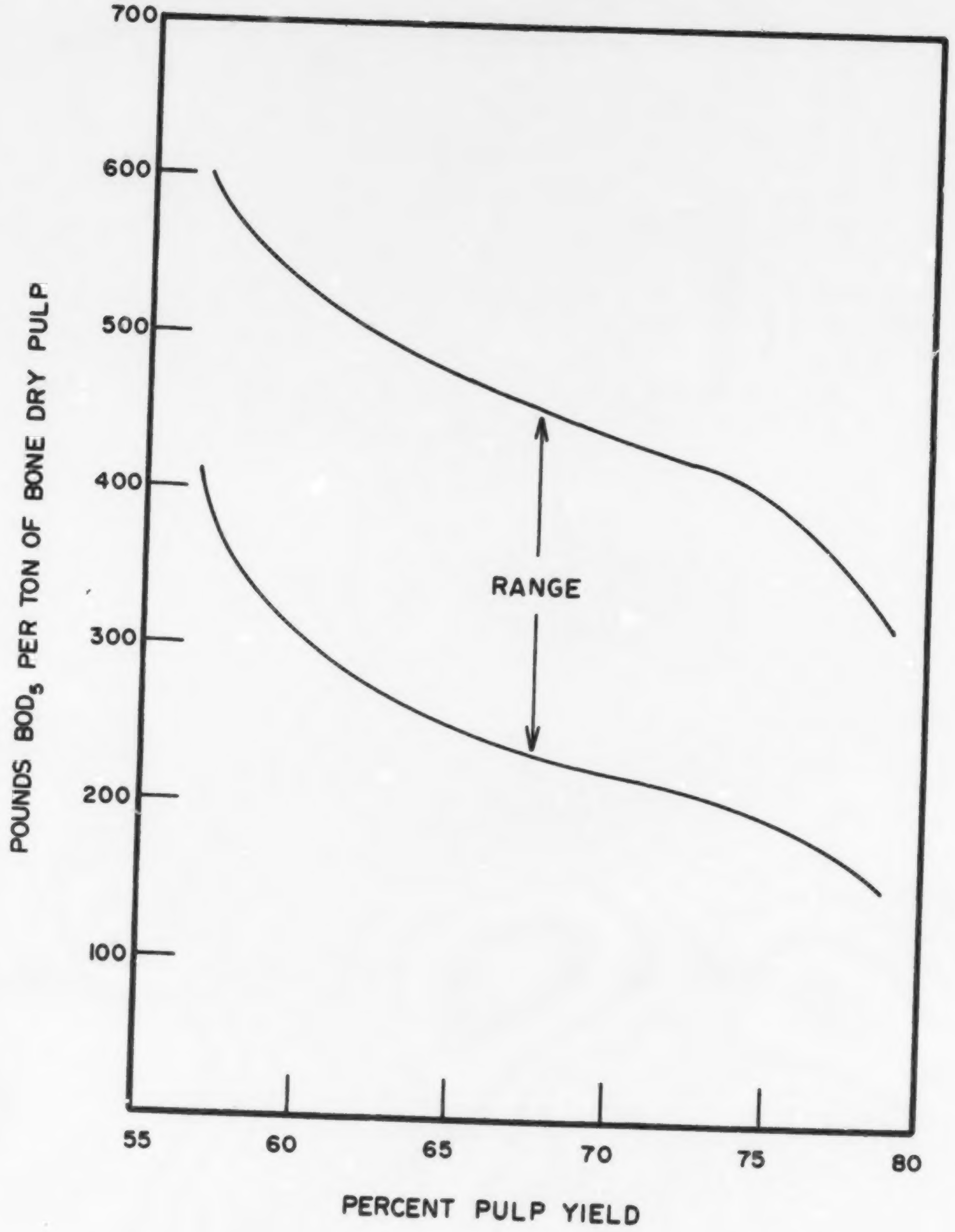
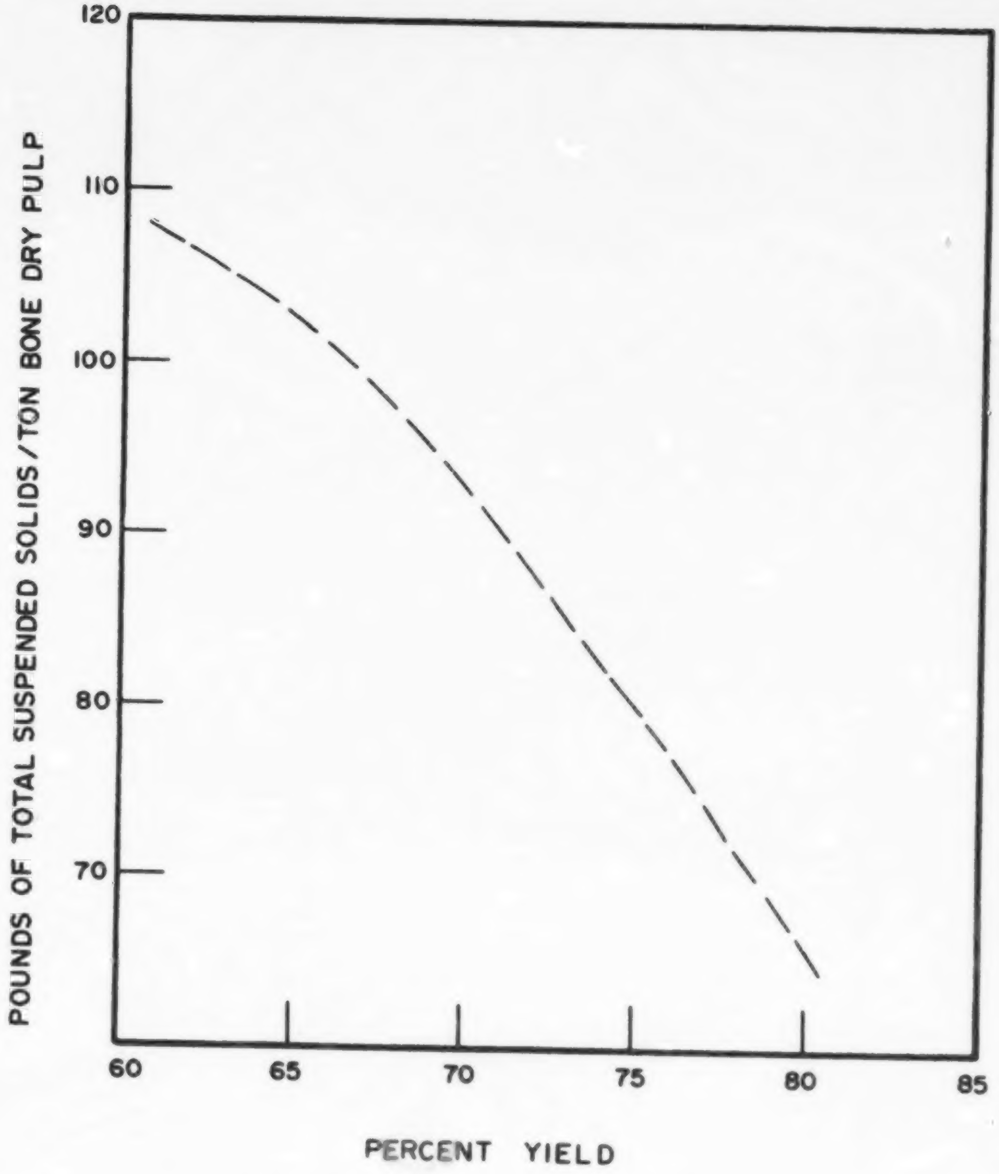


FIGURE 16 SUSPENDED SOLIDS LOSSES FROM NSSC PULPING

(WITHOUT RECOVERY)



The raw waste load is also affected by the methods used to dispose or recover the waste liquor. Evaporation and incineration which is commonly practiced by NSSC mills has been reported to contribute up to one third of the total $BOD_5$ raw waste load. The additional waste load is due to the evaporator condensate plus the carryover of spent liquor solids which occurs during evaporation.

Raw waste data for NSSC mills are shown in Tables 14 and 15. The identity of mills in Table 15 was not available and some of these mills may be included in Table 14. The average $BOD_5$ raw waste load for mills in Table 15 was 25.2 kg/kkg (50.4 lbs/ton) with a range of 11 to 45 kg/kkg (22 to 90 lbs/ton) (not including L-NS-13; inclusion would disproportionately affect the average). The average TSS raw waste load was 12.3 kg/kkg (24.6 lbs/ton) with a range of 4 to 23 kg/kkg (8-46 lbs/ton) (not including L-NS-13), but the TSS analytical techniques are unknown. The average effluent flow for mills in Table 14 was 42,950 liters/kkg (10,300 gal/ton) with a range of 20,000 to 106,700 liters/kkg (4,800 to 25,600 gal/ton) (not including NS-5, inclusion of which would disproportionately affect the average).

The effects of furnish and waste liquor handling can be seen in Table 14. The $BOD_5$ raw waste load for mill NS-1 was 8.5 kg/kkg (17 lbs/ton) while the $BOD_5$ raw waste load for mill NS-2 was 31 kg/kkg (62 lbs/ton). The effluent flow was nearly the same for the mills and thus the difference in raw waste loads apparently relates to the type of furnish and the waste liquor handling systems. Mill NS-1 utilizes waste paper for approximately 33% of its furnish whereas mill NS-2 uses waste paper for only 6% of its furnish. Also, mill NS-1 spray irrigates it strong waste liquor and mill NS-2 recovers the waste liquor through evaporation and incineration. The data presented in Table 14 for mills NS-3, NS-4, and NS-5 may indicate that the effects of waste liquor handling are much more significant than the amount of waste paper utilized as furnish in affecting the raw waste load.

Sodium base NSSC mills which practice extensive internal recycle and other in-plant measures, as described in Section VII, have succeeded in reducing raw waste pollutants to the lower levels shown in Table 15 (32). For example, $BOD_5$ loadings of 28.5 kilograms per metric ton (57 lbs/ton) at a flow of 7094 liters/kkg (1700 gallons per ton) have been reported (33). As flow is progressively reduced through more extensive in-plant measures, $BOD_5$ can be reduced to 14.5 kilograms per metric ton (29 lbs/ton) at 2921 liters/kkg (700 gallons per ton). The lower value cannot be sustained, however, because of operational problems ( 32 ) discussed in Section VII.

## TABLE 14

## RAW WASTE CHARACTERISTICS

## NSSC - SODIUM BASE

| Mill | FLOW kiloliters/kkg (1000 gal/ton) | Waste Paper Furnish % | BOD5 kg/kkg (lbs/ton) | TSS kg/kkg (lbs/ton) | Remarks |
|---|---|---|---|---|---|
| NS-1 | 44.6(10.7) | 33 | 8.5(17) | 8.5(17) | (a) |
| NS-2 | 48.8(11.7) | 6 | 31(62) | 17.5(35) | (b) |
| NS-3 | - | 33 | 35(70)* | - | (b) |
| NS-4 | - | 27-37 | 24(48)* | - | (b) |
| NS-5 | - | 17-21 | 31(62)* | - | (b) |

* per kkg(ton) pulp

(a) Spent liquor is spray irrigated.

(b) Evaporation and incineration of spent liquor.

Notes: Data for mills NS-1 and NS-2 are from mill records of daily discharge data over one year's time. Data for mills NS-3, NS-4, and NS-5 are from mill reports to the NCASI of annual waste loads.

## TABLE 15

### Raw Waste Characteristics

### NSSC - Sodium Base

| Mill | Flow kiloliters/kkg (1000 gal/ton) | $BOD_5$ kg/kkg (lbs/ton) | TSS* kg/kkg (lbs/ton) |
|---|---|---|---|
| L-NS-1 | 38.0 (9.1) | 15.0 (30) | 7.5 (15) |
| L-NS-2 | 20.0 (4.8) | 32.0 (64) | 6.0 (12) |
| L-NS-3 | 30.0 (7.2) | 21.5 (43) | 4.5 (9) |
| L-NS-4 | 25.0 (6.0) | 13.5 (27) | 8.5 (17) |
| L-NS-5 | 7.1 (1.7) | 28.5 (57) | 4.0 (8) |
| L-NS-6 | 47.2 (11.3) | 30.5 (71) | 21.5 (43) |
| L-NS-7 | 41.7 (10.0) | 45.0 (90) | 14.0 (28) |
| L-NS-8 | 43.4 (10.4) | 21.0 (42) | 16.5 (33) |
| L-NS-9 | 106.8 (25.6) | 23.5 (47) | 11.5 (23) |
| L-NS-10 | 83.5 (20.0) | 29.5 (69) | 23.0 (46) |
| L-NS-11 | 29.2 (7.0) | 21.5 (43) | 50.0 (100) |
| L-NS-12 | 43.0 (10.3) | 11.0 (22) | 17.5 (37) |
| L-NS-13 | 100.2 (24.0) | 75.0 (150) | 20.0 (40) |

*Note: TSS measuring techniques unknown.

Similarly, others (33) have reported a short-term average of 5.5 kg/kkg (11 lbs/ton) for BOD5. Again, operating difficulties are cited at this low level, and daily variations of BOD5 range up to 25 kg/kkg (50 lbs/ton) and higher.

Total dissolved solids is frequently measured in the raw waste from NSSC mills, since it is a relatively rapid indicator of upsets. As dissolved solids exceed 1.5 percent due to increased recycle, reports of increased operating problems have been reported (32). A surveyed sodium base mill reported no operating problems due to total dissolved solids at the much lower level of 0.2 percent. Others (33) reported difficulties in meeting wet strength requirements of the product when total dissolved solids of the recirculated white water reached 3.7 percent.

A process flow and materials diagram for a 227 kkg per day (250 ton per day) sodium base NSSC corrugating board mill is shown in Figure 17.

## Neutral Sulfite Semi-Chemical (Ammonia Base)

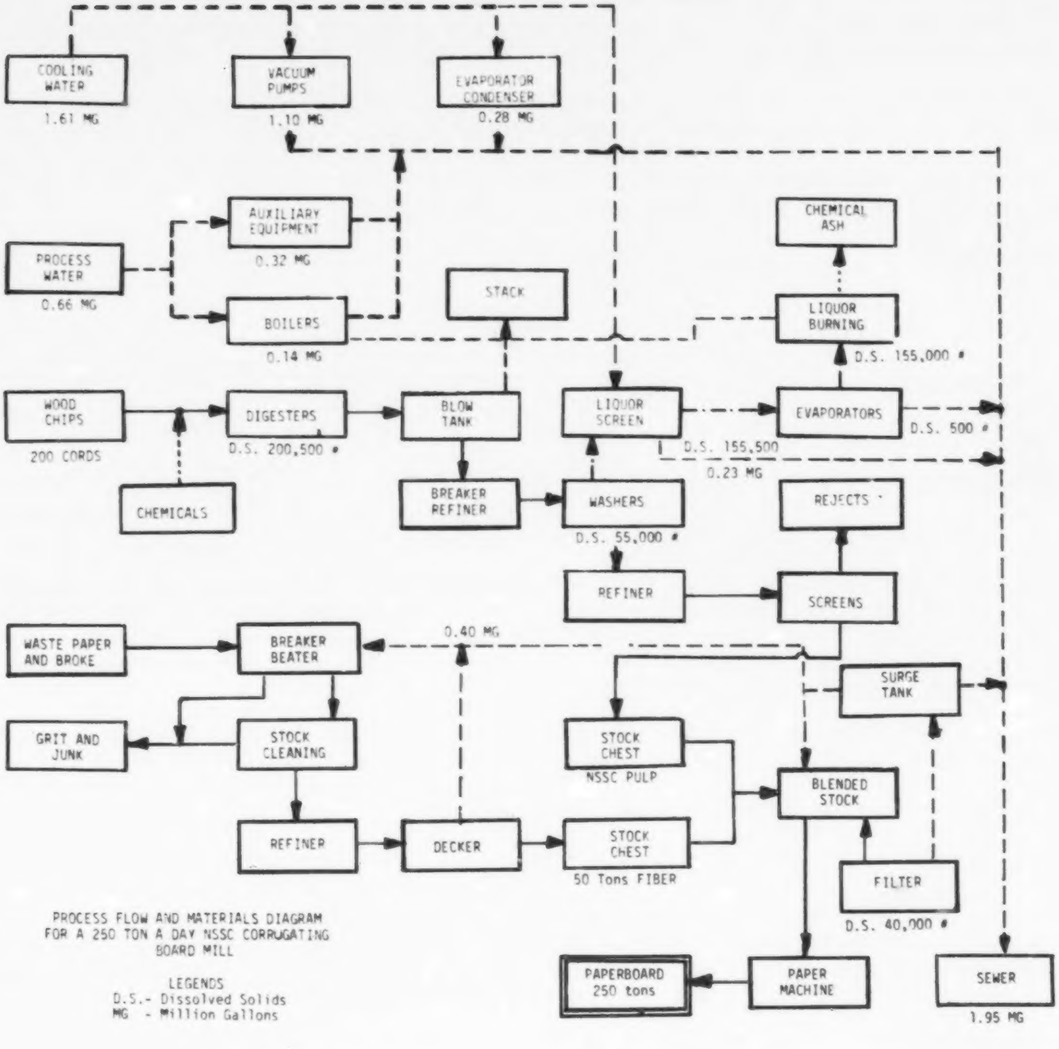
The ammonia base process is similar to the sodium base process described above, except that ammonia is utilized in the preparation of cooking liquor in place of sodium. Waste water characteristics of the two processes are similar, as shown in Table 22, except for the nitrogen concentration in the liquid wastes from the ammonia base mills.

The wood preparation step does not generate a significant waste stream since it is essentially a bark removal and chipping operation. This generates a small stream of approximately 37.8 - 56.7 liters (10-15 gallons) per minute emanating from the chip washer.

The initial phase of pulp preparation begins with heating the chips in a steaming vessel. The chips are then conveyed by a series of horizontal and vertical screw feeders upward through the cooking liquor and into the digester. The cooking liquor consists of ammonium sulfite, produced on site, and anhydrous ammonia. The pressure and temperature in the digestor are controlled by injection of live steam. The digested chips are fed continuously to refiners where they pass between stationary and rotating discs, after which the refined pulp passes into a blow tank to be mixed and diluted to the proper consistency. The vapor and steam from the blow tank are condensed and used elsewhere. From the blow tank, the pulp goes into a two-stage, counter-current washer and then into a high density storage chest. From here the pulp is pumped to the secondary refiner and into the blend chest. The weak black liquor from the washers, and any other wasted cooking liquor, goes to the evaporators. The vapor off the evaporators is condensed and goes to the sewer while the remaining black liquor is burned in a liquor disposal unit.

The paper production stage begins after the pulp has been washed, refined and blended. Pulp is removed from the blend chest and processed

## Figure 17


COOLING WATER
1.61 MG
VACUUM PUMPS
1.10 MG
EVAPORATOR CONDENSER
0.28 MG
AUXILIARY EQUIPMENT
0.32 MG
CHEMICAL ASH
PROCESS WATER
0.66 MG
STACK
LIQUOR BURNING
BOILERS
0.14 MG
D.S. 155,000 #
WOOD CHIPS
200 CORDS
DIGESTERS
D.S. 200,500 #
BLOW TANK
LIQUOR SCREEN
EVAPORATORS
D.S. 500 #
D.S. 155,500
0.23 MG
CHEMICALS
BREAKER REFINER
WASHERS
D.S. 55,000 #
REJECTS
REFINER
SCREENS
WASTE PAPER AND BROKE
BREAKER BEATER
0.40 MG
SURGE TANK
GRIT AND JUNK
STOCK CLEANING
STOCK CHEST
NSSC PULP
BLENDED STOCK
REFINER
DECKER
STOCK CHEST
50 Tons FIBER
FILTER
D.S. 40,000 #
PAPERBOARD
250 tons
PAPER MACHINE
SEWER
1.95 MG

PROCESS FLOW AND MATERIALS DIAGRAM
FOR A 250 TON A DAY NSSC CORRUGATING
BOARD MILL

LEGENDS
D.S.- Dissolved Solids
MG - Million Gallons

through refiners, the third and last refining step. Before going to the paper machine, the pulp passes through cleaners and screens. Excess white water from the paper machine flows through a disc-type saveall, where wood fiber is recovered.

## Waste Water Flow

There are five sources of waste water in the manufacturing process: 1) the evaporators, 2) the powerhouse and maintenance, 3) the pulp mill, 4) the paper machine, and 5) the waste paper plant. The latter, however, is an insignificant source.

In the surveyed mill which produced 453 metric tons (500 short tons) per day, all chips are washed before entering the digester for removal of sand and dirt. Reuse-water from the hot water tank in the pulping area is used as wash water. According to a mill study on July 17, 1972, the chip washer contained the following effluent load:

| | |
|---|---|
| Flow | 81.3 liters/min (21.5 gpm) |
| SS | 78.8 mg/l |
| Total Solids | 98 mg/l |
| Nonvolatiles | 7.6% (of total solids) |

The chips washer discharges directly to a drainage ditch leading to the holding pond. The above numbers refer to the raw solids load before discharge into the holding pond.

No raw water is used in the pulping area. The most significant point for water usage is at the washers where reuse water from the paper machine vacuum system is used.

Excepting floor drains, the water discharge into the pulp mill sewer comes from the screw feeder and the paper machine saveall. To accomplish sufficient high dry solids content in the chips before the digester, water is pressed out of the chips in the screwfeeder. The screwfeeder effluent is a low flow high $BOD_5$ concentrated stream which contributes about 18-20 percent to the total raw $BOD_5$ load of the mill (Jan. 1972). A study carried out by the mill in Nov. - Dec. 1971 showed the following effluent load from the screw feeder:

| | |
|---|---|
| Flow | 340 liters/min (90 gpm) |
| $BOD_5$ | 4260 mg/l (range 2180-6080) |
| $BOD_5$ | 2090 kg/day (4600 lbs/day) |

The saveall overflow is highly variable both in flow and concentrations depending on the amount of clarified water taken for reuse. It is also high in $BOD_5$ load since it contains the dry solids loss from the washers. This stream discharges to the pulp mill sewer.

The weak liquor recovered in the washing plant is evaporated in a quadruple evaporator unit to about 52 percent dryness. The thick liquor is burned in the recovery boiler, or disposed of on land or sold. The combustion products are gaseous with a negligible redsidue of inorganic ash. The gaseous products contain significant sulfur dioxide emissions.

Fresh water is used in the evaporation plant vacuum system and in the boiler area as makeup water to the boilers. The cooling water to the surface condenser may be recycled through a cooling tower.

The most significant effluent stream is the secondary condensate. The condensate can be separated in three streams.

- combined condensate from middle effects
- condensate from the surface condenser
- direct cooling water from the spray condenser and steam ejector.

The combined condensate plus the surface condenser condensate can be diverted in one stream and discharged through a boilout tank. This stream contains a high BOD5 and ammonia load.

The waste loads to the evaporation plant and the effluent from the plant are summarized below for two tests during 1972 and 1973 in Table 16. As can be seen, the condensate BOD5 and ammonia concentrations experience wide variations.

Effluent is discharged from the following points in the paper machine area:

- floor drains
- gland water
- felt conditioners
- centri-cleaners

The effluent discharges to a separate sewer and is metered separately.

Table 17 shows raw waste characteristics for the combined condensates sewer, the papermill sewer, and the total mill sewer. Table 18 shows the raw waste characteristics of the surveyed mill based on mill records of daily discharge data over a year's time. The average raw waste BOD5 for the mill was 33.75 kg/kkg (67.5 lbs/ton) and the TSS raw waste was 17 kg/kkg (34 lbs/ton) based on NSM.

Table 16

Evaporation Plant Waste Load Reduction and Secondary Condensate Discharge Loads

| | | Weak Black Liquor | Combined Condensate |
|---|---|---|---|
| **March 1, 1972** | | | |
| Flow | liters/min (gpm) | 983 (260) | 839 (222) |
| BOD5 | mg/l | 37,900 | 7,520 |
| | kg/day (lbs/day) | 49,900 (110,000) | 8,540 (18,800) |
| | % of Mill Load | | 60-75 |
| | % Reduction: Evaporation plant | 81 | |
| NH3-N | mg/l | 7,000 | 2,600 |
| | kg/day (lbs/day) | 9,260 (20,400) | 2,910 (6,400) |
| | % Reduction Evaporation plant | 69 | |
| **January 1973** | | | |
| Flow | liters/min (gpm) | 680 (180) | |
| NH3-N | mg/l | 9,600 | |
| | kg/day (lbs/day) | 9,400 (20,700) | 1,750 (3,860) |

Table 17

Raw Waste Characterization
NSSC - $NH_3$-N

| | Combined Condensate | Paper Mill Sewer | Total Mill Sewer |
|---|---|---|---|
| Flow kiloliters/day (MGD) | 1,020 (0.27) | 7,180 (1.9) | 12,470 (3.3) |
| BOD5* mg/l | 6,120 | 620 | 630 |
| BOD5* kg/day (lbs/day) | 6,260 (13,800) | 4,470 (9,840) | 7,850 (17,300) |
| Suspended Solids mg/l | 5 | 970 | 620 |
| Suspended Solids kg/day (lbs/day) | 5 (11) | 6,950 (15,300) | 7,760 (17,100) |
| Kjeldahl Nitrogen mg/l | 2,180 | 285 | 210 |
| Kjeldahl Nitrogen kg/day (lbs/day) | 2,230 (4,910) | 2,050 (4,520) | 2,640 (5,810) |
| Ammonia Nitrogen mg/l | 1,700 | 100 | 150 |
| Ammonia Nitrogen kg/day (lbs/day) | 1,740 (3,830) | 750 (1,650) | 1,880 (4,130) |

* Soluble

## Table 18

### Raw Waste Characteristics
### NSSC - Ammonia Base

| Mill | Flow kiloliters/kkg (1000 gal/ton) | BOD5 kg/kkg (lbs/ton) | TSS* kg/kkg (lbs/ton) |
|---|---|---|---|
| N-1 | 34.8 (8.33) | 33.75 (67.5) | 17 (34) |

*NSM

## Kraft - NSSC (Cross Recovery)

Methods employed for introducing spent sodium base NSSC liquor into a kraft recovery system are illustrated in Figure 7 in Section III. While this is the simplest and most economic solution to the recovery problems of this process, it can create some operational difficulties in recovery which must be overcome, as is discussed in Section III.

Assuming solution of these problems, if the ratio of the NSSC operation does not exceed 1:3 of the kraft production, the waste characteristics are not seriously altered. At this ratio, the BOD5 and total suspended solids losses are increased to a small degree over those of kraft recovery alone. NSSC pulp does not wash as well as kraft and thus, more fines pass off in the effluent . However, in modern operations these increases are not anticipated to exceed 10 percent of an equivalent amount of kraft pulp alone on the basis of the 1:3 production ratio. Treatability by biological oxidation processes is not altered by the addition of NSSC pulping to kraft production and electrolyte concentration of the effluent is not altered appreciably.

The raw waste characteristics for unbleached kraft-NSSC (cross recovery) mills are shown in Table 19. The average raw waste BOD5 load for the mills in Table 19 was 19.4 kg/kkg (38.8 lbs/ton) with a range from 14 to 27 kg/kkg (28 to 54 lbs/ton) (not including mill X-10, inclusion of which would disproportionately affect the average. The average raw waste TSS load was 20.5 kg/kkg (41 lbs/ton) with a range from 12.45 to 28.5 kg/kkg (24.9 to 57 lbs/ton), but data were only available for two mills which were using SM. The average flow for mills X-1 through X-4 was 58,380 liters/kkg (14,000 gal/ton) with a range from 43,370 to 74,230 liters/kkg (10,400 to 17,800 gal/ton).

## Paperboard from Waste Paper

The raw waste load of paperboard from waste paper mills is generated in the stock preparation area and is mainly a function of the type of raw materials and additives used. In general, the higher the percentage of kraft or neutral sulfite waste paper used in the furnish, the higher the BOD5 value per ton of product. Mills whose wastes have the higher BOD5 value generally include those that employ an asphalt dispersion system in the stock preparation process in order to melt and disperse the asphalt found in corrugated waste paper. This system subjects the fiber to a heat and pressure environment in a press and digester which contributes to the higher BOD5 loads. A process flow and materials diagram of a typical paperboard from waste paper mill is shown in Figure 18.

Effluent volume, BOD5, and total suspended solids data for 42 mills have been collected and are presented in Table 20. The data were compiled

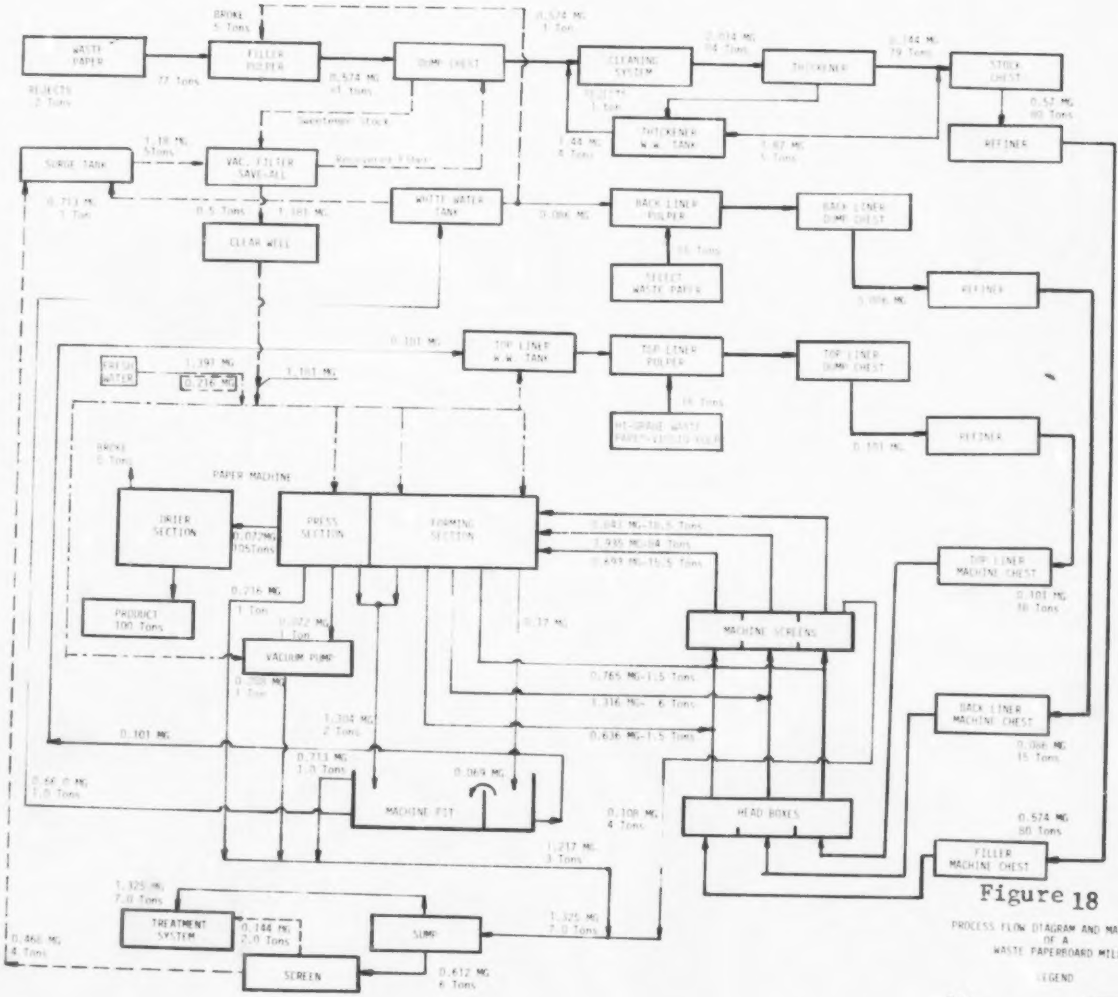

WASTE PAPER
REJECTS 2 Tons
77 Tons
BROKE 5 Tons
FILLER PULPER
0.574 MG 81 Tons
DUMP CHEST
0.574 MG 1 Ton
CLEANING SYSTEM
REJECTS 1 ton
2.014 MG 84 Tons
THICKENER
0.144 MG 79 Tons
STOCK CHEST
0.52 MG 80 Tons
REFINER
THICKENER W.W. TANK
1.44 MG 4 Tons
1.87 MG 5 Tons
Sweetener Stock
SURGE TANK
1.18 MG 5Tons
VAC. FILTER SAVE-ALL
Recovered Fiber
0.713 MG 1 Ton
0.5 Tons
1.181 MG
WHITE WATER TANK
0.086 MG
CLEAR WELL
BACK LINER PULPER
BACK LINER DUMP CHEST
15 Tons
SELECT WASTE PAPER
REFINER
0.086 MG
FRESH WATER
1.397 MG
0.216 MG
1.181 MG
0.101 MG
TOP LINER W.W. TANK
TOP LINER PULPER
TOP LINER DUMP CHEST
10 Tons
HI-GRADE WASTE PAPER-VIRGIN PULP
REFINER
0.101 MG
BROKE 0 Tons
PAPER MACHINE
DRIER SECTION
0.072MG 105Tons
PRESS SECTION
FORMING SECTION
PRODUCT 100 Tons
0.216 MG 1 Ton
0.022 MG 1 Ton
VACUUM PUMP
0.288 MG 1 Ton
0.17 MG
0.641 MG-10.5 Tons
1.935 MG-84 Tons
0.693 MG-15.5 Tons
MACHINE SCREENS
0.765 MG-1.5 Tons
1.316 MG- 6 Tons
0.636 MG-1.5 Tons
TOP LINER MACHINE CHEST
0.101 MG 10 Tons
BACK LINER MACHINE CHEST
0.086 MG 15 Tons
0.101 MG
1.304 MG 2 Tons
0.713 MG 1.0 Tons
0.069 MG
MACHINE PIT
0.66 0 MG 1.0 Tons
0.108 MG 4 Tons
HEAD BOXES
0.574 MG 80 Tons
FILLER MACHINE CHEST
1.217 MG 3 Tons
1.325 MG 7.0 Tons
TREATMENT SYSTEM
0.144 MG 2.0 Tons
SUMP
1.325 MG 7.0 Tons
0.466 MG 4 Tons
SCREEN
0.612 MG 6 Tons
LEGEND
STOCK
PROCESS WATER
FRESH WATER
EXTENSIVE WATER RE-USE

Figure 18

PROCESS FLOW DIAGRAM AND MATERIALS
OF A
WASTE PAPERBOARD MILL

## TABLE 19

## RAW WASTE CHARACTERISTICS

## UNBLEACHED KRAFT - NSCC (CROSS RECOVERY)

| Mill | FLOW kiloliters/kkg (1000 gal/ton) | BOD5 kg/kkg (lbs/ton) | TSS kg/kkg (lbs/ton) |
|---|---|---|---|
| X - 1 | 57.5(13.8) | 24(48) | 28.5(57) |
| X - 2 | 58.8(14.1) | 17(33.9)* | 9.7(19.4)* |
| X - 3 | 43.4(10.4) | 16.3(32.6) | 12.5(24.9) |
| X - 4 | 74.2(17.8) | -( -) | - |
| X - 5 | - | 14(28) | - |
| X - 6 | - | 15.5(31) | - |
| X - 7 | - | 17.5(35) | - |
| X - 8 | - | 21.5(43) | - |
| X - 9 | - | 27(54) | - |
| X - 10 | - | 42.5(85) | - |

* Primary Treatment Effluent; TSS: NSM.

Notes: Data for mills X - 1 through X - 4 are from mill records of daily discharge data over one year's time. Data for mills X - 5 through X - 10 are from mill reports to the NCASI of annual average waste loads.

## TABLE 20

## PAPERBOARD FROM WASTE PAPER RAW WASTE CHARACTERISTICS

| Mill | Effluent Volume Kiloliters/kkg (1000 gal/ton) | BOD5 kg/kkg (lbs/ton) | TSS* kg/kkg (lbs/ton) |
|---|---|---|---|
| L-P-1 | 45.9 (11.0) | 18.0 (36) | 61.0 (122) |
| L-P-2 | 61.9 (16.3) | 21.0 (42) | 61.5 (123) |
| L-P-3 | 35.5 (8.5) | 7.5 (15) | 43.5 (87) |
| L-P-4 | 59.7 (14.3) | 11.0 (22) | 49.0 (98) |
| L-P-5 | 16.7 (4.0) | 8.0 (16) | 4.0 (8) |
| L-P-6 | 45.1 (10.8) | 6.5 (13) | 10.0 (20) |
| L-P-7 | 90.1 (21.6) | 7.0 (14) | 20.0 (8) |
| L-P-8 | 41.7 (10.0) | 8.0 (16) | 21.0 (42) |
| L-P-9 | 83.5 (20.0) | 18.0 (36) | 14.0 (28) |
| L-P-10 | 40.5 (9.7) | 10.0 (20) | 16.5 (33) |
| L-P-11 | 39.6 (9.5) | 9.0 (18) | 14.0 (28) |
| L-P-12 | 41.7 (10.0) | 9.5 (19) | 9.0 (18) |
| L-P-13 | 39.6 (9.5) | 37.5 (75) | 33.5 (67) |
| L-P-14 | 28.0 (6.7) | 6.0 (12) | 7.0 (14) |
| L-P-15 | 62.6 (15.0) | 32.5 (67) | 53.0 (106) |
| L-P-16 | 51.7 (12.4) | 11.5 (23) | 21.0 (42) |
| L-P-17 | 43.0 (10.3) | 12.0 (24) | 29.5 (59) |
| L-P-18 | 13.8 (3.3) | 16.0 (32) | 10.5 (21) |
| L-P-19 | 48.0 (11.5) | 6.0 (12) | 10.5 (21) |
| L-P-20 | 24.2 (5.8) | 9.0 (18) | 17.0 (34) |
| L-P-21 | 65.9 (15.8) | 8.0 (16) | 13.5 (27) |
| L-P-22 | 52.2 (12.5) | 21.0 (42) | 38.0 (76) |
| L-P-23 | 38.8 (9.3) | 11.0 (22) | 15.0 (30) |
| L-P-24 | 24.2 (5.8) | 8.0 (16) | 9.0 (18) |
| L-P-25 | 55.9 (13.4) | 5.0 (10) | 10.5 (21) |
| L-P-26 | 53.0 (12.7) | 12.0 (24) | 15.0 (30) |
| L-P-27 | 31.3 (7.5) | 17.5 (35) | 16.5 (33) |
| L-P-28 | 80.1 (19.2) | 14.5 (29) | 20.0 (40) |
| L-P-29 | 25.1 (6.6) | 23.0 (46) | 14.5 (29) |
| L-P-30 | 69.3 (16.6) | 8.0 (16) | 32.5 (65) |
| L-P-31 | 54.2 (13.0) | 18.0 (36) | 20.0 (40) |
| L-P-32 | 47.6 (11.4) | 11.0 (22) | 21.5 (43) |
| L-P-33 | 25.0 (6.0) | 8.5 (17) | 34.0 (68) |
| L-P-34 | 39.6 (9.5) | 7.0 (14) | 16.0 (32) |
| L-P-35 | 41.7 (10.0) | 12.5 (25) | 8.0 (16) |
| L-P-36 | 43.4 (10.4) | 10.0 (20) | 7.0 (14) |
| L-P-37 | 35.9 (8.6) | 6.0 (12) | 7.0 (14) |
| L-P-38 | 100.1 (24.0) | 12.5 (25) | 27.0 (54) |
| L-P-39 | 41.7 (10.0) | 12.5 (25) | 35.0 (70) |
| L-P-40 | 43.4 (10.4) | 10.0 (20) | 8.0 (16) |
| L-P-41 | 35.9 (8.6) | 6.0 (12) | 7.0 (14) |
| L-P-42 | 52.2 (12.5) | 13.0 (26) | 9.0 (18) |

*Analytical technique unknown.

from data collected by the Michigan Water Resources Commission (34), the Wisconsin Water Resources Commission (35), and the NCASI (36). The volume of effluent ranged from 13,760 to 100,150 liters/kkg (3,300 to 24,000 gal/ton) with an average of 45,870 liters/kkg (11,000 gal/ton). It is known that at three of the mills the effluent has been virtually eliminated through clarification and water reuse. However, these mills manufacture a small number of products of coarse grade which makes this procedure possible.

The minimum quantity of water required also depends on whether or not food packaging grades of board are produced. If they are not, a reduction of discharge to the 12,510 - 16,680 liters/kkg (3,000-4,000 gal/ton) level may be achieved. If they are, reuse is somewhat restricted since taste and odor-producing substances tend to accumulate in the system and adversely affect the product. Slimicides usage is likewise limited since some of these also impart odors. Hence, the minimum practical discharge for a mill producing food board is generally considered to be about 29,190-41,700 liters/kkg (7,000-10,000 gal/ton). Practically all products can be produced in this effluent range. As discussed in Section IV, mills frequently produce food board in conjunction with non-food board and therefore minimum practical flows range anywhere from 16,680-41,700 liters/kkg (4000-10,000 gal/ton).

Total suspended solids losses for the 42 mills listed range from 4.0 to 61.5 kg/kkg (8 to 123 lbs/ton) of product; 27 containing 20 kg/kkg (40 lbs/ton) or under. The average TSS for the mills in Table 20 was 19.2 kg/kkg (38.4 lbs/ton) (not including mill L-P-1 and mill L-P-2, inclusion of which would disproportionately affect the average). The identity of the mills in Table 20 is not available and thus the TSS analytical measurement techniques are unknown. This value depends upon the type of save-all employed for fiber recovery, and the application of the more effective types is contingent upon the kinds of waste paper used and the products manufactured. All mills of this type can employ a cylinder-type save-all and, while it is not the most effective type, it serves to separate usable from unusable fiber and ordinarily restricts losses to less than 20 kg/kkg (40 lbs/ton). It also serves to protect effluent treatment systems from slugs of fiber and clarifiers from flotation problems.

$BOD_5$ values ranged from 5 to 37.5 kg/kkg (10 to 75 lbs/ton) of product, 30 of the 42 being less than or equal to 12.5 kg/kkg (25 lbs/ton). Residual pulping liquor, starch, and other adhesives, such as glutens, accounted for most of the $BOD_5$. Raw waste characteristics are also shown in Table 21 for 23 mills which may be included in Table 20 since the identification of the mills in Table 20 are not available. The average $BOD_5$ raw waste load for all mills in Table 21 was 11.25 kg/kkg (22.5 lbs/ton) with a range of 4 to 20 kg/kkg (8 to 40 lbs/ton). The average $BOD_5$ raw waste load was 12.7 kg/kkg (25.4 lbs/ton) and 9.0 kg/kkg (18.0 lbs/ton) for mills P-1 through P-14 and mills P-15 through P-23, respectively. The TSS raw waste load for mills P-16 through P-23 ranged from 2.8 to 81 kg/kkg (5.6 to 162 lbs/ton). Effluent flows

## TABLE 21
## RAW WASTE CHARACTERISTICS

## PAPERBOARD FROM WASTE PAPER

| Mill | FLOW kiloliters/kkg (1000 gal/ton) | BOD5 kg/kkg (lbs/ton) | TSS kg/kkg (lbs/ton) |
|---|---|---|---|
| P-1 | - | 7.5(15) | - |
| P-2 | - | 15(30) | - |
| P-3 | - | 12(24) | - |
| P-4 | - | 12(24) | - |
| P-5 | - | 13.5(27) | - |
| P-6 | - | 7(14) | - |
| P-7 | - | 5.5(11) | - |
| P-8 | - | 15(30) | - |
| P-9 | - | 12.5(25) | - |
| P-10 | - | 10(20) | - |
| P-11 | - | 18.5(37) | - |
| P-12 | - | 13(26) | - |
| P-13 | - | 16.5(33) | - |
| P-14 | - | 20(40) | - |
| P-15 | 68.4(16.4) | 16(32) | 72.5(145)* |
| P-16 | 12.1( 2.9) | 10(20) | 9( 18) |
| P-17 | 19.6( 4.7) | 6(12) | - |
| P-18 | 38.8( 9.3) | 5.5(11)** | 35( 70) |
| P-19 | 5( 1.2) | 4( 8) | 4.8(9.5) |
| P-20 | 47.5(11.4) | 7.5(15) | 6.5( 13) |
| P-21 | 9.6( 2.3) | 9.5(19) | 2.8(5.6) |
| P-22 | 38.8( 9.3) | 9(18) | 7.5( 15) |
| P-23 | 139.3(33.4) | 12.5(25) | 81(162) |

*NSM
**Primary Treatment Effluent

Notes: Data for mills P-1 through P-14 are from mill reports to the NCASI of annual average waste loads. Data for mills P-15 through P-23 are from mill records of daily or weekly discharge data over one year's time.

averaged 29,940 liters/kkg (7,180 gal/ton) with a range of 5000 to 68,400 liters/kkg (1,200 to 16,400 gal/ton) (not including mill P-23). Mill P-23 produces all food board and has a correspondingly high flow as described earlier, of 139,300 liters/kkg (33,400 gal/ton). However, it is reported that the mill P-23 flow is atypically high and could possibly be reduced to relatively lower levels without detriment to the products.

The raw waste load discharged by the mills in this industry is a matter of some interpretation as the tendency to treat waste water for reuse prior to biological treatment has become more typical for the industry. The practice has taken the form of the use of in plant treatment facilities or an out of plant primary clarifier for the removal of suspended solids from the process white water prior to reuse on the wet end and other selected areas in the mill. The recovered solids are recycled for reuse in the stock system in either case and the excess water not returned to the mill represents the waste volume discharged to biological treatment or to municipal waste treatment facilities. The raw waste load attributable to the mills using the above systems is the volume of waste water after reuse. Those mills that practice only nominal reuse of process water but provide primary, biological and secondary solids removal facilities generate a primary clarifier effluent waste load that equates to the raw waste load of the mills practicing reuse. A comparison of the raw waste load of mills using any one of the three different systems described above in response to their pollution control problem shows that the primary clarifier effluent of each is the most equatable parameter. That this is the most representative raw waste load for a mill is supported by the nearly industry wide practice of recycling all primary clarifier sludge back to the process. Under these conditions the clarifier influent does not represent the actual waste load leaving the mill.

The use of this criterion for defining raw waste loads for mills in this category becomes more significant when considering the fourth response to pollution abatement which is receiving wider use in this industry. This requires the recycle of process water to the extent that the fresh water use for process purposes equals the evaporation rate from the process system. The waste water that is generated is both the raw waste load and final discharge for these mills. This waste is generally the result of intermittent discharges from holding basins used to contain the many variables associated with production requirements including excessive stock dumps, grade changes, or mill wash ups. Achievement of this goal is made by differing routes. One approach utilizes a well designed in-plant treatment facility with safeguards designed into the system to accommodate process variations and upsets. Another utilizes the outer plant primary clarifier effluent with surge storage tanks and screening equipment on the water return to the mill to insure reliability of the quality of the recycle water. There are a few mills in this industry which have been built within the last ten years that have designed into the process plans at the engineering stage the concept of complete process water recycle. This approach utilizes one or the other of both solids removal systems described above and includes extensive noncontact cooling water collection and recycled fresh water systems used in noncontaminating areas and discharged separately to the environment without treatment. In addition, selective process water use and recycle practices are designed into the plant at the engineering phase. One such mill was included in this study in order to obtain reliable information regarding the waste loads generated in the process water systems and the final effluent. This mill did not employ biological treatment on the final discharge, however, the waste load discharged to the environment was significantly lower than the discharge from mills with primary settling and biological treatment facilities.

Using data obtained at mills practicing all four methods of treatment and recycle, the following comparisons can be made. The BOD5 of the discharge by mills with secondary treatment facilities averaged 0.65 kg/kkg (1.3 lbs/ton) and that for the mill without biological treatment but with near complete recycle achieved 0.075 kg/kkg (0.15 lbs/ton) BOD5 and far lower waste loads than achieved by the other mills in total suspended solids. However, for this mill the concentrations of contaminants were considerably higher in the final discharge to the environment. Perhaps more importantly the concentrations of dissolved solids attributable to the extensive recycle of process water reached significantly high levels, 1800 mg/l BOD5 and 7500 mg/l total dissolved solids (TDS), which this particular production process was able to tolerate.

Evaluation of the results obtained by the four basic approaches made by this industry to the pollution control effort supports the fact that the waste waters generated respond well to the biological treatment process for the reduction of BOD5 and to a lesser extent, except with near complete recycle, dissolved solids. The waste is generally deficient in phosphorus and nitrogen making necessary the addition of nutrients to achieve good biological treatment performance and is low in heavy metals concentration, rarely exceeding one mg/l.

These wastes are substantially neutral although some grades of paper board lean toward the acid side due to the large amount of alum used as sizing. They seldom, however, contain mineral acidity and can be treated biologically without neutralization. They generally contain relatively little true color unless such is imparted by the water supply, but can be quite turbid due to the presence of clay or titanium dioxide used in the process or entering the system with the waste paper. The turbidity varies over a wide range depending on the production grade being run in the mill. However, evaluation of the data obtained during the survey program carried out at mills in this subcategory demonstrates that clarification followed by biological treatment reduces the turbidity from 200 to 700 JTU (Jackson Turbidity Units) to 15 to 35 JTU. It can be concluded that the installation of treatment facilities for the reduction of BOD5 will generally reduce turbidity to acceptable levels.

Historically, the raw waste water for mills in this industry has been characterized in terms of a particular manufacturing process and by the raw materials used in the process. The realization of near complete reuse of process water by some mills indicates that the reuse factor becomes paramount when characterizing the waste loads discharged to the environment on an industry-wide basis.

There are other factors that exert an adverse influence on the quantity and quality of the waste water generated by paperboard from waste paper mills on an intermittent basis. Virtually all mills change from one grade of product to another during an operating cycle. The frequency of this occurrence varies from two or three changes in a 24-hour period to only once in three or four days. The effect on the waste water generated may be negligible or quite obvious, depending on the difference in the grade change being made. Generally the suspended solids increases with an attendant increase in $BOD_5$. The duration of this import is from perhaps 15 minutes to one hour after which the waste stream returns to normal conditions. Production scheduling generally avoids following a production grade with a completely different grade in order to reduce the interim period of production that meets neither grade specification. This, therefore, tends to minimize the impact of grade change on waste water quality except where it is unavoidable.

Mill washups occur perhaps once a week; however, in recent years many mills have extended their operating period to 14 and 21 day cycles. This extended period frequently coincides with a felt or wire life cycle which permits a felt or wire to be changed during a scheduled mill shutdown. A mill shut down largely influences the suspended solids content of the waste stream. These solids have accumulated in various tanks and chests throughout the process system over the operating cycle and are generally considered to be undesirable for return to the production process. Some mills reuse a substantial amount of the solids generated by a washup, others reuse virtually none. In either case the primary clarifier removes these solids from the waste stream and the excess is disposed of via the clarifier underflow system to sludge dewatering ponds or vacuum filtration prior to land disposal.

## PAPER MACHINES

The manufacture of paper involves two relatively discrete process systems in terms of quantity and quality of water utilizations, namely the wet end and the dry end of the machine. Refined pulp stock is discharged to the machine chest from which it enters the wet end of the paper machine. The stock is pumped to a headbox which meters the quantity of stock to the paper machine. Process water is added to reduce the stock consistency to 0.25-0.5 percent either in the headbox or the vat, depending on whether the forming section is a cylinder or fourdrinier machine.

The stock deposits on a cylinder or fourdrinier wire and excess machine white water passes through the wire. A large portion of this white water is recycled back through the machine stock loop, and the excess is pumped to a white water collection chest for reuse in the stock preparation area. Any remaining excess goes to a save-all for fiber collection and white water clarification. These showers clean areas which tend to develop fiber buildup and represent the largest portion of raw waste water generated by a paper machine.

The sheet is carried by cloth felts to the forming and press sections where additional quantities of water are removed. Felt cleaning showers which add more excess water are used. They are required, however, in order to maintain the drainability of the felt. The sheet passes through the drier section to the dry end where water use is generally low in volume and consists principally of cooling water. If on-machine coating is practiced it involves a coating kitchen in which the coating is made up to specifications and applied in successive applications to the sheet. The presence of this operation generates a low volume waste water relatively high in $BOD_5$ and dissolved solids.

Many mills utilize a broke pulper on the dry end of this machine. This represents the largest single water use in this area and is generally recycled white water. However, this system component is responsible for creating process water system imbalances of the greatest magnitude. Since a dry end break requires that the entire tonnage of the machine be reduced to pulp consistency the volume of water needed to accomplish this is very high. The imbalance created depends on the duration of the break and generally is reflected by an increase of volume with an attendant increase in suspended solids and, to a lesser extent, $BOD_5$ and dissolved solids in the mill effluent. During this period the treatment facilities may be subject to two or three times the average waste load generated by the mill. The subsequent impact on the performance of the mill waste treatment facilities is not documented, however. Since treatment capabilities are a function of time and kilograms of contaminant per unit of time, the impact must exert an influence which is hidden in the 24-hour average waste load data reported by the mill.

Impact of this system on a mill practicing near complete recycling of process water is probably more critical. Normal operation requires facilities for recycling process water within the machine loop and the stock preparation loop, and from one loop to the other. To accommodate a dry end or wet end break, the process water system must be capable of responding quickly to the need for a large volume of process water at either the wet end or dry end of the machine without utilizing fresh water make-up. This system must also have the capacity to bring this volume of water back into the process water system without losses to the mill discharge sewer.

## TABLE 22

## SUMMARY

## RAW WASTE CHARACTERISTICS

| Subcategory | FLOW kiloliters/kkg (1000 gal/ton) |  | BOD5 kg/kkg (lbs/ton) |  | TSS kg/kkg (lbs/ton) |  |
|---|---|---|---|---|---|---|
|  | Range | Ave | Range | Ave | Range | Ave |
| Unbleached Kraft | 39.2-85.5<br>(9.4-20.5) | 52.5<br>(12.6) | 12-28<br>(24-56) | 16.9<br>(33.8) | 19-28<br>(38-56) | 21.9<br>(43.8) |
| NSSC-Ammonia | -<br>(-) | 34.8<br>(8.3) | -<br>(-) | 33.5<br>(67.0) | -<br>(-) | 17*<br>(34)* |
| NSSC-Sodium | 20.0-106.7<br>(4.8-25.6) | 42.9<br>(10.3) | 11-45<br>(22-90) | 25.2<br>(50.4) | 4-23<br>(8-46) | 12.3**<br>(24.6)** |
| Kraft-NSSC | 43.4-74.2<br>(10.4-17.8) | 58.4<br>(14.0) | 14-27<br>(28-54) | 19.4<br>(38.8) | 12.4-28<br>(24.9-57) | 20.5<br>(41) |
| Paperboard Waste Paper | 5.0-68.4<br>(1.2-16.4) | 29.9<br>(7.2) | 4-20<br>(8-40) | 11.2<br>(22.5) | 2.8-91<br>(5.6-162) | -<br>(-) |

*NSM
**TSS Analytical Technique unknown

# SECTION VI

## SELECTION OF POLLUTANT PARAMETERS

### WASTE WATER PARAMETERS OF SIGNIFICANCE

A thorough analysis of the literature, mill records, sampling data which has been derived from this study, and all of the other sources discussed previously demonstrates that the following constituents represent pollutants according to the Water Pollution Control Act for the subcategories under study:

Biochemical Oxygen Demand (5-day, 20°C) ($BOD_5$)
Total Suspended Solids
pH
Color (Not including Paperboard from Waste Paper)
Ammonia Nitrogen (NSSC-Ammonia base only)

### RATIONALE FOR SELECTION OF IDENTIFIED PARAMETERS

### Biochemical Oxygen Demand (5-day, 20°C) ($BOD_5$)

Biochemical oxygen demand (BOD) is a measure of the oxygen consuming capabilities of organic matter. The $BOD_5$ in pulp and paper mill effluents is a result of the various pulp and paper making processes as shown in Sections III and V. The $BOD_5$ does not in itself cause direct harm to a water system, but it does exert an indirect effect by depressing the oxygen content of the water. Sewage and other organic effluents during their processes of decomposition exert a $BOD_5$, which can have a catastrophic effect on the ecosystem by depleting the oxygen supply. Conditions are reached frequently where all of the oxygen is used and the continuing decay process causes the production of noxious gases such as hydrogen sulfide and methane. Water with a high $BOD_5$ indicates the presence of decomposing organic matter and subsequent high bacterial counts that degrade its quality and potential uses.

Dissolved oxygen (DO) is a water quality constituent that, in appropriate concentrations, is essential not only to keep organisms living but also to sustain species reproduction, vigor, and the development of populations. Organisms undergo stress at reduced DO concentrations that make them less competitive and able to sustain their species within the aquatic environment. For example, reduced DO concentrations have been shown to interfere with fish population through delayed hatching of eggs, reduced size and vigor of embryos, production of deformities in young, interference with food digestion, acceleration of blood clotting, decreased tolerance to certain toxicants, reduced food efficiency and growth rate, and reduced maximum sustained swimming speed. Fish food organisms are likewise affected adversely in conditions with suppressed DO. Since all aerobic aquatic organisms need a certain amount of oxygen, the consequences of total lack of dissolved oxygen due to a high BOD5 can kill all inhabitants of the affected area.

If a high BOD5 is present, the quality of the water is usually visually degraded by the presence of decomposing materials and algae blooms due to the uptake of degraded materials that form the foodstuffs of the algal populations.

## Total Suspended Solids (TSS)

Total suspended solids (or suspended solids) is a measure of nondissolved solids in the waste water which are trapped or "suspended" on a test filter medium. Suspended solids in pulp and paper mill effluents are generally fibrous materials lost in the pulping of wood and production of paper. Most of these suspended solids can be removed by primary treatment with most of the remainder removed by secondary treatment. The suspended solids discharged from pulp and paper mill secondary treatment systems are generally biological organisms generated in the secondary treatment system in the removal of BOD5, and thus are not characteristic of the suspended solids in the raw waste. The biological suspended solids in pulp and paper mill effluents have the following detrimental effects upon receiving waters: (1) increases in turbidity of the receiving water resulting in reduced light transmission and accompanying effects, such as reduced photosynthesis, (2) degradation of aesthetic values, (3) settling of suspended solids to the bottom of receivng waters, and (4) exertion of BOD by the biological suspended solids. The BOD exerted by the biological suspended solids is only partially measured by the BOD5 test as the BOD20 would be more descriptive of the oxygen consuming effects. A general description of suspended solids and effects upon receiving waters is given below.

Suspended solids include both organic and inorganic materials. The inorganic components include sand, silt, and clay. The organic fraction includes such materials as grease, oil, tar, animal and vegetable fats, various fibers, sawdust, hair, and various materials from sewers. These solids may settle out rapidly and bottom deposits are often a mixture of both organic and inorganic solids. They adversely affect fisheries by covering the bottom of the stream or lake with a blanket of material that destroys the fish-food bottom fauna or the spawning ground of fish. Deposits containing organic materials may deplete bottom oxygen supplies and produce hydrogen sulfide, carbon dioxide, methane, and other noxious gases.

In raw water sources for domestic use, state and regional agencies generally specify that suspended solids in streams shall not be present in sufficient concentration to be objectionable or to interfere with normal treatment processes. Suspended solids in water may interfere with many industrial processes, and cause foaming in boilers, or encrustations on equipment exposed to water, especially as the temperature rises. Suspended solids are undesirable in water for textile industries; paper and pulp; beverages; dairy products; laundries; dyeing; photography; cooling systems, and power plants. Suspended particles also serve as a transport mechanism for pesticides and other substances which are readily sorbed into or onto clay particles.

Solids may be suspended in water for a time, and then settle to the bed of the stream or lake. These settleable solids discharged with man's wastes may be inert, slowly biodegradable materials, or rapidly decomposable substances. While in suspension, they increase the turbidity of the water, reduce light penetration and impair the photosynthetic activity of aquatic plants. Solids in suspension are aesthetically displeasing. When they settle to form sludge deposits on the stream or lake bed, they are often much more damaging to the life in water, and they retain the capacity to displease the senses. Solids, when transformed to sludge deposits, may do a variety of damaging things, including blanketing the stream or lake bed and thereby destroying the living spaces for those benthic organisms that would otherwise occupy the habitat.

When of an organic and therefore decomposable nature, solids use a portion or all of the dissolved oxygen available in the area.

## pH, Acidity, and Alkalinity

The effluent from a typical biological treatment process will normally have a pH in the range of 6.0 to 9.0, which is not detrimental to most receiving waters. However, the application of some technologies at pulp and paper mills for the removal of color, solids, and nitrogen can result in major adjustments in pH. The effluent limitations which are cited insure that these adjustments are compensated prior to final discharge of treated wastes in order to avoid harmful effects within the receiving waters. A general description of pH, acidity, and alkalinity and their effects upon receiving waters follows.

Acidity and alkalinity are reciprocal terms. Acidity is produced by substances that yield hydrogen ions upon hydrolysis and alkalinity is produced by substances that yield hydroxyl ions. The terms "total acidity" and "total alkalinity" are often used to express the buffering capacity of a solution. Acidity in natural waters is caused by carbon dioxide, mineral acids, weakly dissociated acids, and the salts of strong acids and weak bases. Alkalinity is caused by strong bases and the salts of strong alkalies and weak acids.

The term pH is a logarithmic expression of the concentration of hydrogen ions. At a pH of 7, the hydrogen and hydroxyl ion concentrations are essentially equal and the water is neutral. Lower pH values indicate acidity while higher values indicate alkalinity. The relationship between pH and acidity or alkalinity is not necessarily linear or direct.

Waters with a pH below 6.0 are corrosive to water works structures, distribution lines, and household plumbing fixtures and can thus add such constituents to drinking water as iron, copper, zinc, cadmium and lead. The hydrogen ion concentration can affect the "taste" of the water. At a low pH water tastes "sour". The bactericidal effect of chlorine is weakened as the pH increases, and it is advantageous to keep the pH close to 7. This is very significant for providing safe drinking water.

Extremes of pH or rapid pH changes can exert stress conditions or kill aquatic life outright. Dead fish, associated algal blooms, and foul stenches are aesthetic liabilities of any waterway. Even moderate changes from "acceptable" criteria limits of pH are deleterious to some species. The relative toxicity to aquatic life of many materials is increased by changes in the water pH. Metalocyanide complexes can increase a thousand-fold in toxicity with a drop of 1.5 pH units. The availability of many nutrient substances varies with the alkalinity and acidity. Ammonia is more lethal with a higher pH.

The lacrimal fluid of the human eye has a pH of approximately 7.0 and a deviation of 0.1 pH unit from the norm may result in eye irritation for the swimmer.

## Color

Color is defined as either "true" or "apparent" color. In *Standard Methods for the Examination of Water and Wastewater* (4), the true color of water is defined as "the color of water from which the turbidity has been removed." Apparent color includes "not only the color due to substances in solution, but also due to suspended matter." In the various chemical pulping processes, lignin and lignin derivatives are solubilized and removed from the wood during the cooking process. The spent cooking liquors containing these highly colored compounds are removed from the pulp in a washing sequence following the cooking process. The wash water is highly colored, and large amounts of color are ultimately discharged to the receiving stream despite some recovery operations.

Color has the following detrimental effects upon receiving waters: (1) color retards sunlight transmission and interferes with photosynthesis thereby reducing the productivity of the aquatic community; (2) color alters the natural stream color which detracts from the visual appeal and recreational value of the receiving waters; (3) color has effects upon downstream municipal and industrial water users, such as higher water treatment costs, difficulties in water treatment, and a multitude of industrial process operating problems; (4) color bodies complex with metal ions, such as iron or copper, forming tar-like residues which remove the metals from the stock available to stream organsims for normal metabolism, and the complexes can have direct inhibitory effects on some of the lower scale of organisms in the aquatic community and thereby reduce the productivity of the receiving water; (5) color, derived from lignin, is an indicator of the presence of potentially inhibitory compounds and in addition may have direct inhibitory effects upon some of the lower scale organisms in the food chain, (6) color in receiving waters affects fish movements and fish productivity, and (7) color bodies exert a long term BOD (20-60 days up to 100 days) not measured by the $BOD_5$ test.

Color limitations in Sections X and XI are for color as measured by the techniques specified in NCASI Technical Bulletin #253 (December 1971) (See Appendix V) (2).

## Ammonia Nitrogen

Nitrogen is a nutrient which can contribute to excessive growth of algae and other aquatic vegetation when discharged in significant quantities. Pulp and papermaking waste flows normally contain only minor concentrations of this nutrient, and nitrogen compounds must often be added to provide desired biological waste treatment efficiencies. As a result, effluent limitations on nitrogen are not considered necessary. The one exception regarding limitations is for the ammonia base NSSC subcategory. Large quantities of ammonia nitrogen can be released to the waste water from the industrial process itself. Failure to substantially reduce this pollutant could be highly detrimental to receiving waters. A general description of ammonia nitrogen and the detrimental effects to receiving waters is given below.

Ammonia is a common product of the decomposition of organic matter. Dead and decaying animals and plants along with human and animal body wastes account for much of the ammonia entering the aquatic ecosystem. Ammonia exists in its non-ionized form only at higher pH levels and is the most toxic in this state. The lower the pH, the more ionized ammonia is formed and its toxicity decreases. Ammonia, in the presence of dissolved oxygen, is converted to nitrate ($NO_3$) by nitrifying bacteria. Nitrite ($NO_2$), which is an intermediate product between ammonia and nitrate, sometimes occurs in quantity when depressed oxygen conditions permit. Ammonia can exist in several other chemical combinations including ammonium chloride and other salts.

Nitrates are considered to be among the poisonous ingredients of mineralized waters, with potassium nitrate being more poisonous than sodium nitrate. Excess nitrates cause irritation of the mucous linings of the gastrointestinal tract and the bladder; the symptoms are diarrhea and diuresis, and drinking one liter of water containing 500 mg/l of nitrate can cause such symptoms.

Infant methemoglobinemia, a disease characterized by certain specific blood changes and cyanosis, may be caused by high nitrate concentrations in the water used for preparing feeding formulae. While it is still impossible to state precise concentration limits, it has been widely recommended that water containing more than 10 mg/l of nitrate nitrogen ($NO_3$-N) should not be used for infants. Nitrates are also harmful in fermentation processes and can cause disagreeable tastes in beer. In most natural water the pH range is such that ammonium ions ($NH_4^+$) predominate. In alkaline waters, however, high concentrations of un-ionized ammonia in undissociated ammonium hydroxide increase the toxicity of ammonia solutions. In streams polluted with sewage, up to one half of the nitrogen in the sewage may be in the form of free ammonia, and sewage may carry up to 35 mg/l of total nitrogen. It has been shown that at a level of 1.0 mg/l un-ionized ammonia, the ability of hemoglobin to combine with oxygen is impaired and fish may suffocate. Evidence indicates that ammonia exerts a considerable toxic effect on all aquatic life within a range of less than 1.0 mg/l to 25 mg/l, depending on the pH and dissolved oxygen level present.

Ammonia can add to the problem of eutrophication by supplying nitrogen through its breakdown products. Some lakes in warmer climates, and others that are aging quickly are sometimes limited by the nitrogen available. Any increase will speed up the plant growth and decay process.

## RATIONALE FOR PARAMETERS NOT SELECTED

### Settleable Solids

Settleable solids are a measure of that fraction of suspended solids which settles after one hour in a quiescent vessel. While a few mills have measured settleable solids, reliable data are not generally or widely available. Since settleable solids are measured as a part of the suspended solids, settleable solids are not considered a separate pollutant.

### Turbidity

Turbidity is an expression of the optical property of the fine suspended matter in a sample of water. The suspended matter may be clay, silt, finely divided organic and inorganic matter, plankton, and other microscopic organisms. The suspended matter causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. The paperboard from waste paper subcategory has been reported having mill effluents which may have high turbidities. However, turbidity is not considered as a pollutant parameter because treatment systems installed to reduce $BOD_5$ will also reduce turbidity.

## Coliform Organisms

The fecal coliform test is the most valid microbiological parameter for pulp and paper effluents presently available. The excessive densities of fecal coliforms and more specifically, Klebsiella pneumoniae, as measured by the fecal coliform test, in pulp and paper mill effluents are significant. Klebsiella can complicate E. coli detection, they can be pathogenic, and they are coliforms by definition. In addition, Klebsiella are found in the intestinal tract of approximately 30% of humans and 40% of animals. Klebsiella reflect the high nutrient levels in pulp and paper mill wastes. With adequate treatment for reduction of nutrients, densities of Klebsiella and also total coliforms should be significantly reduced.

Coliforms are not included as a separate pollutant parameter because (1) an adequate data base is lacking for the pulp and paper industry, (2) adequate biological treatment should reduce fecal coliform levels to less than 1000/100 mls, and (3) disinfection techniques for reduction of coliforms in pulp and paper mill effluents may be more harmful to the environment than the coliforms. A general description of coliforms is given below.

Fecal coliforms are used as an indicator since they have originated from the intestinal tract of warm blooded animals. Their presence in water indicates the potential presence of pathogenic bacteria and viruses.

The presence of coliforms, more specifically fecal coliforms, in water is indicative of fecal pollution. In general, the presence of fecal coliform organisms indicates recent and possibly dangerous fecal contamination. When the fecal coliform count exceeds 2,000 per 100 ml there is a high correlation with increased numbers of both pathogenic viruses and bacteria.

Many microorganisms, pathogenic to humans and animals, may be carried in surface water, particularly that derived from effluent sources which find their way into surface water from municipal and industrial wastes. The diseases associated with bacteria include bacillary and amoebic dysentery, Salmonella gastroenteritis, typhoid and paratyphoid fevers, leptospirosis, chlorea, vibriosis and infectious hepatitis. Recent studies have emphasized the value of fecal coliform density in assessing the occurrence of Salmonella, a common bacterial pathogen in surface water. Field studies involving irrigation water, field crops and soils indicate that when the fecal coliform density in stream waters exceeded 1,000 per 100 ml, the occurrence of Salmonella was 53.5 percent.

## Resin Acids

Soaps of resin acids (isopimaric, abietric, and dehydroabietric) have been identified as causing 80 percent of the biologically deleterious effects of unbleached kraft mill effluent. Studies in Canada indicates that these compounds are contained mainly in combined condensates rather than black liquor. The most recent studies indicate that a reduction in biologically deleterious effects can be achieved by a well designed and operated biological treatment system. This parameter is not considered as a separate pollutant parameter for any of the subcategories because adequate biological treatment systems generally will reduce resin acids. However, data are lacking to determine the extent of the reductions.

## Polychlorinated Biphenyls

Polychlorinated biphenyls (PCB's) are chemically and thermally stable compounds found in paper and paperboard manufacture and are known to cause deleterious effects upon biological organisms. They have been shown to concentrate in food chains and few restrictions on their control exist at present. Recycled office papers are the main source in the paper industry at present, although occasionally paperboard extracts show evidence of Monsanto's Aroclor 1254 (PCB) from environmental and other sources. Quantities of PCB in recycled paperboard are generally between 1 and 10 mg/1, but may be more or less. Functional barriers or lines in paperboard are seen to provide food stuff protection until PCB's are purged from the system through process waters, volatilization and paper destruction. This parameter is not considered as a separate pollutant parameter for any of the subcategories because an adequate data base does not exist.

# SECTION VII

## CONTROL AND TREATMENT TECHNOLOGIES

Waste water effluents discharged from the subject subcategories of the industry to receiving waters can be reduced to required levels by conscientious application of established in-plant process control together with water recycle measures and by well designed and operated external treatment facilities. Present technology will not allow achievement of zero discharge.

This section describes both the in-plant and external technologies which are either presently available or under intensive development to achieve various levels of pollutant reduction for each of the subcategories. In some cases the "in-plant" and "external" technologies merge. For example, a mill may employ extensive suspended solids removal equipment internally, reusing both the clarified water for manufacture and the recovered solids in the product, whereas another similar mill may depend to a greater extent on "external" suspended solids removal to arrive at a similar end point.

Tables 23 and 24 summarize internal and external alternative technologies which are in present use or under development.

## Table 23

## SUMMARY OF INTERNAL TECHNOLOGIES

| | Subcategory | | | | |
|---|---|---|---|---|---|
| | Unbl. Kraft | NSSC Ammon. | NSSC Sodium | Kraft-NSSC | Paperboard from Waste Paper |
| I. PULP MILL | | | | | |
| A. General | | | | | |
| Gland water reduction/reuse | X | X | X | X | X |
| Vacuum pump seal water reduction/reuse | X | X | X | X | X |
| Internal spill collection | X | X | X | X | X |
| B. Wood Handling | | | | | |
| Dry Handling | X | X | X | X | |
| Wet Handling with recycle | X | X | X | X | |
| C. Digestion & Pulp Washing | | | | | |
| Hot stock screening | X | | | X | |
| Knot removal and/or reuse | X | X | X | X | |
| Wash water reuse | X | X | X | X | |
| D. Spent Cooking Liquors | | | | | |
| Chemical recovery | X | X | X | X | |
| Land disposal or sale | | X | X | | |
| Condensate reuse | X | X | X | X | |
| Dregs recovery | X | | | X | |
| II. PAPER MILL | | | | | |
| Reuse of white water | X | X | X | X | X |
| Saveall system | X | X | X | X | X |
| Shower water reduction/reuse | X | X | X | X | X |
| Gland water reduction/reuse | X | X | X | X | X |
| Vacuum pump seal water reduction/reuse | X | X | X | X | X |
| Internal spill collection | X | X | X | X | X |

Note: Data were generally not available to accurately determine the percentage use by mills in each subcategory of the internal technologies.

## Table 24

## SUMMARY OF EXTERNAL TECHNOLOGIES

### I Technologies in general use.

| BASIC FUNCTION | ALTERNATIVE TECHNOLOGIES |
|---|---|
| Screening | Traveling, self-cleaning<br>Fixed bars |
| Neutralization | Automatic pH control<br>Manual pH control |
| Suspended Solids Removal | Mechanical Clarifier (C)<br>Earthen Basin (L)<br>Dissolved Air Flotation (DAF) |
| BOD5 removal | Aerated Stabilization Basin (ASB)<br>Activated Sludge (AS)<br>Storage oxidation (SO) |
| Foam control | Chemical<br>Mechanical |

Estimated percentage use of above alternatives by subcategory:

| TECHNOLOGY | UNBLEACHED KRAFT | NSSC AMMONIA | NSSC SODIUM | KRAFT NSSC | PAPERBOARD FROM WASTE PAPER |
|---|---|---|---|---|---|
| (C) | 50 | 50 | 20 | 80 | 80 |
| (L) | 30 | *10 | 10 | 10 | 15 |
| (DAF) | *10 | 10 | 10 | 10 | *10 |
| (ASB) | 50 | 50 | 40 | 60 | 30 |
| (AS) | *10 | *10 | *10 | *10 | 30 |
| (SO) | 45 | *10 | *10 | 40 | *10 |

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* means "less than"

Note: Mills discharging into public sewers are excluded from above percentage estimates.

Table 24 (Cont'd)

## II Advanced technologies.

| BASIC FUNCTION | ALTERNATIVE TECHNOLOGIES |
|---|---|
| Color removal | Lime treatment<br>Activated carbon<br>Coagulation-alum<br>Reverse osmosis |
| Suspended Solids Removal | Filtration (i.e. sand or multi-media) |

## III Color Removal Technologies - Stage of Development

| Treatment | Type of Installation |
|---|---|
| Lime Treatment | Full Scale |
| Activated Carbon | Pilot Scale |
| Coagulation - Alum | Full Scale |
| Reverse Osmosis | Full Scale |
| Resin Adsorption | Full Scale |
| Ultrafiltration | Pilot Scale |
| Amine Treatment | Bench Scale |
| Ion Flotation | Bench Scale |

## UNBLEACHED KRAFT

### Internal Technologies:

Available methods for reduction of pollutant discharges by internal measures include effective pulp washing, chemicals and fiber recovery, treatment and reuse of selected waste streams and collection of spills and prevention of "accidental" discharges. Internal measures are essentially reduction of pollutant discharges at their origin and result in recovery of chemicals, by-products, and in conservation of heat and water.

Generally, mills which reduce raw waste pollutant loads concomitantly reduce effluent flowage through recycle. An example selected from two surveyed unbleached kraft mills illustrates this point. The raw waste $BOD_5$ load of one such mill was 22.5 kg/kkg (45 lbs/ton) using 58,422 liters/kkg (14,000 gal/ton). The effluent of the second mill contained only 17 kkg/kkg (34 lbs/ton) of $BOD_5$ at a 41,731 liters/kkg (10,000 gal/ton) flow.

Barking of wood prior to pulping is most commonly performed by dry processes which require very little water. This practice is preferred over wet barking from the viewpoint of reducing raw waste load. Where wet barking is employed, the $BOD_5$ and suspended solids losses are not a major percentage of the total waste, as pointed out in Section V. However, as mills reduce their raw waste loads through internal controls, the waste loads from wet barking may become more significant as it will be a larger percentage of the total waste load. Elimination of raw waste loads from wet barking can be achieved through total recycle of the barking water. A closed system for wet barking installed at a mill in California completely is presently very near to a successful closed system.

Treatment of wet barking effluents consists of screening followed by settling to remove fine suspended solids (principally silt). Heavy duty mechanically-raked clarifiers are preferably employed, with a design rise rate of 40,741-48,890 liters per square meter per day (1000-1200 gallons per square foot per day) and a retention time of two hours (12). Clarified effluent may be added to the mill biological treatment system. Settled solids are removed continuously and are readily dewatered for disposal.

In dry drum barking which is employed by many linerboard mills, the wood is sprayed with water on entering the drum to remove soil and loose bark. From 0.83 to 1.67 liters/kkg (0.2 to 0.4 gal/ton) of product is used and in some instances the water is settled and recycled. Overflow from settling ponds is discharged to treatment systems.

Many linerboard mills receive wood in the form of chips either direct from the forest or, more generally, from saw mills. In these cases, no barking is required. As the forest products industry continues its trend toward maximum utilization of the tree, it is likely that more wood will be delivered as chips and less round wood will be barked by pulp mills, thus reducing or eliminating waste water discharges from this source.

After cooking, pulp is washed to remove the dissolved wood substances and spent cooking chemicals. Older practice was to dilute the pulp to about one percent consistency after washing in order to promote effective screening for the removal of knots and shives. Thickening on a decker was then required to raise the consistency for storage purposes. The water removed by the decker typically accounted for about one-third of the total $BOD_5$ loss from the mill.

Normal practice now reduces this loss substantially by a process modification. After cooking, the pulp is passed through a fibrilizer which fractionates the knots remaining with the pulp. The pulp then passes through a specially designed hot stock screen which effectively removes shives prior to washing. This sequence avoids the need for dilution of the pulp for screening after washing, so losses from this source are reduced. This practice is preferred for unbleached kraft pulps as raw waste loads are substantially reduced. Rejected knots and shives, if not recooked, are disposed of on the land and are not permitted in the mill sewer system.

In the kraft recovery process, inert materials originating in the wood and other raw materials must be removed. Inert grits from the lime-slaking operation are generally removed for disposal on the land as are dregs from the white and green liquor clarification steps. This practice reduces the suspended solids loss to the sewer.

Kraft mill condensates are recognized to be the principal BOD contributors to the effluent load from unbleached kraft mills. Consequently, considerable effort has been spent by most kraft operations to consume internally as much of these condensates as possible by substituting them for normal fresh water make-up applications. Most commonly the recycling of condensates has occurred in brown stock washing and in causticizing make-up. Use of condensates in stack scrubbers for lime kilns and disolving tank vents is also a common practice. Direct disposal of condensates has been successfully accomplished by large scale spray irrigation in locations where suitable soil and groundwater conditions are available.

Despite the extensive condensate recycling practices, these waste streams still constitute, collectively, a most serious source of air and water pollution from unbleached kraft operations.

Many of the problems related to condensates evolve from the recycling practices themselves. Ideally, recycling of waste streams assumes that the waste stream is totally consumed in the process - that the polluting materials are destroyed by incineration or homogeneously assimilated into the process streams. This of course is not entirely correct when speaking of condensates. Since condensates in general are black liquor distillates, a large fraction of the offending chemical substances involved are volatile substances which are not amenable to the basic black liquor processing scheme. If this were not so, the materials would not have distilled during the formation of the condensate stream. Recycling the condensate may result in a gradual increase in the concentration of the volatiles in the process stream involved. Consequently, distillate slip streams from the process may become enriched with these volatiles to the extent that serious air and water pollution problems occur in areas where no serious problems exist without the recycling practices. The observed increase in BOD concentration of multi-effect evaporator condensate with extensive recycling of condensates to brown stock washers may serve as an example.

Recycling of condensates to the causticizing system may also result in similar problems. Elevated temperatures at the recovery dissolving tank, slaking and causticizing area, and lime kiln area, may provide a means for purging recycled volatiles from condensates to the atmosphere. Since many of these volatiles are malodorous, it is obvious that the kraft mill odor problem may be greatly enhanced by the recycling practice. Normally innocuous emission sources, such as tank vents and vacuum pump exhausts, may also become fortified through extensive condensate recycling.

Operational problems may also occur with extensive condensate recycling. Increased wet strength additive usage has been linked with the application of multi effect evaporator condensate on brown stock washing. Momentary black liquor carry-over in condensate streams recycled to the causticizing area may seriously disrupt the normal liquor-making process. Unquestionably, many of the side effects of the recycling practices have yet to be defined.

For a large part the condensate streams from the continuous pulping process differs markedly from the batch process. The continuous digester blow generally occurs at a lower temperature and pressure than that of the batch cook. The evolution of distillates in this function is inconsequential in comparison to the batch counterpart. Relief condensate, characteristic of the batch cook, does not occur as such in the continuous cook. However, condensate from continuous digester steaming vessels may be compared with the batch relief condensate.

Condensates from the recovery system evaporators and from condensed blow tank vapors account for about one-third of the total BOD5. Table 25 shows typical reuse points for these condensates. Methanol accounts for about 80 percent of their organic content and for most of the $BOD_5$ (38). Other alcohols, ketones, and small quantities of phenolic substances, sulfur compounds, and terpenes account for the remainder. Because of the odorous compounds, reuse of condensates has been restricted by air pollution considerations. This led, about 10 years ago, to the development of technology to remove such compounds. Steam stripping of condensates has been studied extensively for this purpose (37) (38) (39). Steam stripping has been successfully applied at least at one bleached kraft mill, and another is planning to air strip condensates. It should be noted that this technology is transferable from bleached to unbleached kraft mills.

## TABLE 25
## REUSE OF EFFLUENT FROM DIFFERENT UNIT OPERATIONS

| Type of Effluent | Kiloliters/kkg (gal/ton) | Place of Reuse |
|---|---|---|
| Blow gas condensate, direct | 5.7 - 22.4<br>(1500-5900)<br>Average<br>8.6 (2000) | Brown stock washing<br>Screen room or decker operation<br>Hot water supply<br>Mud Washing<br>Dissolving of additives |
| Blow gas condensate, indirect | 1133 - 1.52<br>(350 - 400) | None (Sewered) |
| Cooling-water for blow-gas condenser, indirect | 1500 - 5900<br>Average:<br>8.6 (2000) | Hot water supply<br>Brown stock washing<br>Bleached stock washing<br>Screen room or decker operation |
| Turpentine-decanter underflow | 0.038 - 0.63<br>(10 - 165)<br>Average:<br>0.19 (50) | Showers on knotter<br>Showers on brown-stock washers |
| Cooling water for turpentine condenser | 2.47 - 9.12<br>(675 - 2440) | Hot water supply<br>Screen room<br>Boiler make-up water<br>Direct blow-heat condenser |
| Evaporator condensate | 2.56 - 10.6<br>(675 - 2800)<br>Average:<br>about<br>5.7 - 7.6 | Brown stock washing<br>Lime kiln scrubber<br>Cooking liquor preparation<br>Mud-washing or dreg washing<br>Woodyard, Wash-ups, Sewer<br>Boiler make-up water |
| Evaporator barometric effluent | 30.4 - 57.0<br>(8000 - 15000) | Transport of bark-boiler fly ash<br>Recycled through cooling-tower |
| Cooling water for evaporator surface condensers | | Hot water supply<br>Machine showers in paper mill |
| Evaporator seal pit, discharge from surface condensers | 1.52 - 5.89<br>(400 - 1550) | Brown stock washing |

A rule of thumb sometimes used in the industry is that one-third to one-half of the $BOD_5$ and suspended solids in the raw waste are due to spills, overflows, and wash-ups which occur when the production process is not in equilibrium. These losses occur due to a variety of factors including breakdown of equipment, routine maintenance, planned shutdowns and startups, power failures, and grade changes. For economic reasons, efforts are made to minimize these occurrences, but even under the best of circumstances, they occur regularly and therefore should be taken into consideration in any waste management program. An example occurred during a survey of one mill. The mill experienced an unusual short-term black liquor loss. This caused raw waste $BOD_5$ to increase from 17 to 29 kg/kkg (34 to 58 lbs/ton Suspended solids increased from 11 to 18.5 kg/kkg (22 to 29 lbs/ton). Such shock loads can interfere with external treatment operation, reducing its removal efficiency. Short-term biological processes are particularly susceptible to upset from shock loads.

The following practices should be employed to eliminate or minimize non-equilibrium losses:

1. Evaporators should be periodically "boiled out" to remove scale and other substances which interfere with efficient operation. A storage tank should be provided to contain the flushed material, which can then be slowly returned to the process when it is again in operation. It should be noted that in the 1950's the flushed material was usually sewered, but presently most operations have the capability of returning the material to the liquors from the pulp washing system or to a special storage tank from where the material can be returned to the process (40).

2. Storage facilities should be provided for weak black liquor, strong black liquor, and recovery plant chemicals and liquors. These should be adequately sized to avoid overflows in approximately 90 percent of process upsets. Provision can be made to return these stored materials to the originating subprocess at a later time.

3. If overflows would cause treatment plant upset or increased discharge of pollutants, production curtailments should be made as required to avoid overflows if the overflows cannot be prevented by some other means. Sewer segregation can be utilized, especially in new mills, to minimize these impacts, in conjuction with adequate storage.

4. Continuous monitoring within mill sewers (especially conductivity) should be employed to give immediate warning of unknown spills so that corrective action can be promptly taken.

5. Personnel should be trained to avoid such spills where possible, and to take immediate corrective action when they occur.

6. Storage lagoons located prior to biological treatment should be provided to accept longer term shock loads. The contents can then be gradually returned to process or to treatment without detriment to treatment operations.

In the stock preparation paper machine systems large quantities of water are necessary to form a sheet of paper. Typically, the fibrous stock is diluted to about 0.5 percent consistency before entering the paper machine itself. Such dilutions are necessary in order to provide uniformity of dispersion of the fibers in the sheet of paper, as well as to provide other desired qualities such as smoothness. Most of this water must be removed in the papermaking process, since only a small amount of moisture, typically five to eight percent by weight, is retained in the final sheet.

A high percentage of this water is removed in the forming section of the machine. In the case of a fourdrinier machine, the water is removed by rolls, called table rolls, or foils located under the endless-belt screen or "wire" onto which the dilute stock is fed. Additional water is removed by suction boxes and a suction couch roll which transfers the sheet from the wire to the felt. In a cylinder machine, the water drains through the screen-covered drums which are immersed in vats containing the dilute stock.

After leaving the forming section of the machine, the sheet of paper or board contains about 80 percent moisture. A press section employing squeeze rolls, sometimes utilizing vacuum, is used to further reduce moisture to a level of about 60 percent. The remaining moisture is removed by steam-heated drying rolls.

Water leaving the forming and press sections is called white water, and approximates 104,325 liters/kkg (25,000 gal/ton). Due to recycling, only a relatively small portion of the total is wasted. Mills which utilize varying amounts of extensive recycling discharge only 2,087 to 20,865 liters/kkg ton (500 to 5000 gal/ton) white water from the system.

As shown in the process flow diagrams for each of the subcategories in Section V, water is used in the manufacture of pulp and paper for a variety of purposes including washing, cooling, transporting, chemical preparation, gland seals, vacuum pump seals, felt washing and washups. In addition, water is a necessary material in the chemical-mechanical process of "hydrating" or "brushing" pulp fibers during stock preparation in order to promote the bonding characteristics required to form a sheet of paper or board.

These uses of water, and the technology available to reduce pollutant loads in the raw waste water, are discussed below.

Recycling of this white water within the stock preparation/papermaking process has long been practiced in the industry, as discussed in Section V. In the last 10 years, further strides in reuse have been made.

Problems associated with increased reuse usually manifest themselves in reduced machine speed and/or product quality. Slime growth due to increase of $BOD_5$ and temperature has been encountered. This problem can be reduced by the proper application of biocides, by better housekeeping, and by design for higher liquor velocities in pipelines, shorter detention times in tanks, and avoidance of pockets in the system. Scale buildup is another problem which can be reduced, principally by chemical and mechanical design techniques. Buildup of dissolved solids can also cause product quality problems, but in the typical case, reuse is limited by slime growth and scale buildup. In addition, corrosion is a significant factor in increased recycling within the white water system.

Most mills employ a save-all to recover fibrous and other suspended material escaping from the paper machine. This is considered by many mills to be a necessity for both economic and pollution control reasons, although some mills can obtain equivalent results by other means. Save-alls are of three principal types. First is the older drum type immersed in a vat containing the waste water. The water passes through the drum, leaving a mat of fiber which is removed continuously for reuse. Second is the newer disc type, which utilizes a series of screen-covered discs on a rotating shaft immersed in the vat. The action is similar to the drum save-all, but the disc type has the advantages of greater filtering area per unit volume and the use of vacuum, both of which reduce space requirements. In both of these types of save-alls a side-stream of "sweetener" fibrous stock is added to the influent to improve the efficiency of suspended solids removal in the main influent feed. The recovered fiber is then removed from the save-all for reuse directly in the manufacturing process. The third type is the dissolved air flotation save-all (DAF). In this type unit air bubbles, formed on the addition of air under pressure, attach themselves to the fibers, causing them to float to the surface, where a continuous mechanical rake recovers them for reuse.

The disc type has enjoyed recent popularity because of its flexibility and higher removal efficiencies in most cases. In addition it provides a positive barrier for fibers preventing their introduction into the clarified white water. DAF units are still popular, however, in paperboard from waste paper mills.

Clarified effluent from save-alls is on the order of 10,433-25,038 liters/kkg (2900-6000 gal/ton) (19), with a suspended solids content of 120 milligrams or less per liter (one pound or less per 1000 gallons), whereas the influent may contain 2398 milligrams or more per liter (20 pounds or more per 1000 gallons).

All or a part of the clarified effluent may be discharged directly to a sewer, but most mills reuse a significant portion of the effluent for such services as (19):

1. Vacuum pump seals
2. Machine showers
3. Stock cleaner elutriation
4. Cooling waters
5. Pulp washing
6. Wash-ups
7. Consistency regulation dilution
8. Barometric evaporator condensers (pulp mill)
9. Repulping of broke and purchased fiber

Vacuum pumps are utilized in paper mills to provide a vacuum source to accelerate the removal of water from fourdrinier machines, presses, save-alls, and other devices and thus the vacuum pump demand for water is somewhat product dependent. Most such pumps are of the ring seal type, which require large amounts of water. This water provides a seal between the moving parts of the pump, and is necessary to avoid backflow of air to the vacuum side. Water used for this purpose approximates 10,433 to 16,692 liters/kkg (2500 to 4000 gal/ton). It must be sufficiently free of suspended solids to avoid plugging of the orifices or other control devices used to meter it to the pump. The formation of scale inside of the pumps can be a problem. Further, it must not be corrosive to the mechanical parts of the pump, and it must be relatively cool (typically less than 32°C (90°F)) to permit development of high vacuums of 0.67-0.74 atm. (20-22 in. Hg.) For lower vacuum requirements 0.17-0.40 atm. (5-12 in. Hg.), somewhat higher temperatures are permissible.

As more extensive recycling is employed in machine systems, the significance of this volume of seal water increases. The use of mechanical seals has reduced the volume of seal water, but they have so far not proven satisfactory in many applications. Reduction of seal water usage is an area which requires more study and development.

Presently, several methods are used to minimize fresh water requirements depending on product as well as mill configuration. Seal water is collected and passed through for reuse directly back to the pumps or to another water-using system. The use of excess white water for vacuum pump sealing, before discharge to sewer or back to process, is also practiced. Another procedure is to utilize the discharged vacuum pump water for cooling of heat exchangers.

Seal water is also used on packing glands of process pumps, agitators, and other equipment employing rotating shafts. It cools bearings, and lubricates the packing, and minimizes leakage of the process fluid. Even though the amount of water used per packing is small -- generally in the range of 1.86 to 11.34 liters per minute (0.5 to 3 gpm) -- the total usage is quite extensive because of the large number of rotating shafts required in the processes. The total usage may approximate 4173-8346 liters/kkg (1000-2000 gal/ton) of paper or board. Methods used to control and reduce quantities required include proper maintenance of packings and flow control of individual seal water lines. In some cases, seal water which leaks from the packing can be collected and reused, usually after filtering.

Water showers are used in both the forming and pressing sections to clean the wire, felts, and other machine elements subject to contact with the stock. Formerly, large volumes of fresh water were used for this purpose. In recent years, attention has focused on the use of recycled white water on showers, and this trend has increased with the development of self-cleaning showers. Even with self-cleaning showers, however, a suspended solids content of less than 120 milligrams per liter (one pound per thousand gallons) is generally desired to avoid plugging. Concurrently, the use of high pressure (up to 52 atm. or 750 psig), low volume showers using fresh water has increased. These are employed where product, operability, cleanliness, or other factors mitigate against the use of white water showers. In many such cases, it is possible to operate these high pressure showers on a time cycle, so that flow occurs only a small percentage, 10 to 20 percent, of the time.

Showers are also used on grooved presses to keep the grooves clean and operable. Grooved presses were developed within the last 10 years and have enjoyed increasing popularity because of their efficiency in water removal, and lower capital and operating cost than the suction (i.e., vacuum) presses which they replace. Recycle of this shower water, usually after filtering to remove fibrous and other suspended solids, is commonly employed.

Whether recycled water or lower volumes of fresh water are used for showers, a reduction in fresh water usage and its concomitant waste water flow results. Significantly, this reduction also decreases the fiber losses to sewer.

Since the 1950's, free-discharge cleaners have been used increasingly to remove dirt and other undesirable materials from the dilute stock prior to its application to the paper machine. These cleaners are the cyclonic type and operate on the centrifugal force principle, utilizing hydraulic pressure drop as the source of energy. They increase cleaning efficiency through a continuous discharge of reject although significant quantities of usable fiber are also rejected. To reduce such losses, the cleaners are usually arranged in stages, so that rejects from previous stages are sent through subsequent stages of smaller size. Rejects from the last stage have a consistency about three percent and are usually sewered. Well designed and operated cleaner systems reject one-half to one percent of production from the final stage. To reduce such losses further, elutriation water is added or in some cases, a closed-discharge cleaner replaces the free-discharge unit in the final stage. Either method reduces sewer losses.

Cooling water is used for bearings, particularly in older mills using sleeve bearings instead of the anti-friction bearings used in new or rebuilt mills. Cooling water is not contaminated and can be collected and reused either directly (after heat removal), or indirectly by discharge into the fresh water system, if heat buildup is not a problem. Similarly, water used to cool brake linings in paper rewind applications may be reused. Water used to cool condensate from the steam dryers can similarly be reused, but because of high heat loads, cooling of this water by cooling towers or other means would usually be necessary. None of the mills surveyed in this study cooled this water. However, one mill surveyed returned dryer condensate directly to the feed water heater at the boiler plant under 1.20-1.34 atm pressure (three-five psig pressure), thereby reducing the cooling water requirement. This approach could be used more generally where dryers are operated at pressures above 1.34 atm. (five psig).

## External Technologies

External control technologies for the treatment of unbleached kraft effluents are discussed below. Specifically, these technologies include technologies for reduction of suspended solids, BOD5, and color. Data on eleven unbleached kraft mills which have secondary treatment and for which secondary treatment effluent data were available are shown in Tables 26 and 27. Specifically, Table 26 shows production, flow, type of treatment, and the TSS analytical measurement technique for each mill. Table 27 shows BOD5 and TSS data for the mills' raw waste and final effluents (Note: AA is the annual average of daily values and MM is the maximum monthly average of daily values). The data generally represent a full year's operation and have been derived from mill records by either EPA or the NCASI.

### Removal of Suspended Solids

The physical process of removing suspended organic and inorganic materials, commonly termed primary treatment, is accomplished either by sedimentation or flotation, or a combination thereof. Screening ahead of treatment units is particularly useful for barking and wood washing effluents and is necessary in all cases to remove trash materials which could seriously damage or clog succeeding equipment. Automatically cleaned screens, operating in response to level control, are commonly employed and represent preferred practice.

Primary treatment can be accomplished in mechanical clarifiers, flotation units, or sedimentation lagoons. Although the latter enjoyed widespread use in the past, the large land requirement, coupled with inefficient performance and high cost for cleaning, has made them less popular in recent years (12).

Dissolved air flotation has been applied to effluents from paperboard from waste paper mills and has achieved removal efficiencies of up to 98 percent of the suspended solids (41). The relatively high cost of flotation equipment, its requirements for flocculating chemicals, high power requirements, and mechanical complexity make it unsuitable for application in other than the capacity of a save-all, except where space

## TABLE 26

## MILL DATA

## UNBLEACHED KRAFT

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment Methods | TSS Methods |
|---|---|---|---|---|
| UK-1 | 1020 (1125) | 39.2 (9.4) | ASB | SM* |
| UK-2 | 824 ( 909) | 50 (12.0) | ASB-SO | SM* |
| UK-3 | 794 ( 875) | 39.6 ( 9.5) | ASB-SO | SM |
| UK-4 | 751 ( 828) | 85.5 (20.5) | ASB-SO | SM |
| UK-5 | 1201 (1324) | 60 (14.4) | ASB | SM |
| UK-6 | 732 ( 807) | 64.2 (15.4) | ASB-SO | SM |
| UK-7 | 641 ( 707) | 112.5 (27.0) | ASB-SO | SM |
| UK-8 | 997 (1099) | 43.4 (10.4) | SO | SM |
| UK-9 | 1376 (1517) | 43.4 (10.4) | ASB | NSM |
| UK-10 | 1464 (1614) | 55.5 (13.3) | ASB-SO | NSM |
| UK-11 | 346 ( 382) | 43.8 (10.5) | ASB-SO | SM |

* Final effluents: SM, raw waste: NSM

## TABLE 27

## MILL EFFLUENT DATA

### UNBLEACHED KRAFT

(All values in kg/kkg (lbs/ton) except as noted)

| | Raw Waste | | Final Effluent | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mill | AA BOD5 | AA TSS | AA BOD5 | MM BOD5 | MM BOD5* | AA TSS | MM TSS | MM TSS* |
| UK-1 | 13.5(27) | 10.5(21) | 1.4(2.8) | 2.3(4.6) | 50 | 4.7(9.4) | 6.1(12.1) | 119 |
| UK-2 | 12.2(24.5) | - | 1.3(1.6) | 1.3(2.7) | 25 | 2.2(4.5) | 3.8( 7.6) | 69 |
| UK-3 | 14(28) | 28(56) | 1.3(1.7) | 2.2(2.4) | 32 | 1.05(2.1) | 1.4( 2.8) | 37 |
| UK-4 | 15.5(31) | 19.5(39) | 4.3(8.7) | 5.2(11.5) | 69 | 7.1(14.2) | 8.8(17.7) | 101 |
| UK-5 | 19(38) | 19.5(39) | 2.1(4.3) | 3.1(6.1) | 55 | 5.6(11.2) | 7.1(14.2) | 124 |
| UK-6 | 21.2(42.5) | 23.3(46.6) | 4.5(2.2) | 3.7(7.4) | 43 | 2.5(5.0) | 3.9( 7.9) | 46 |
| UK-7 | - | - | 2.1(4.2) | 3.1(6.2) | 27 | 3.6(7.2) | 4.6( 9.3) | 34 |
| UK-8 | 19(38) | - | 2.3(4.7) | 3.3(6.6) | 75 | 2.9(5.9) | 3.5( 7.0) | 69 |
| UK-9 | 17.2(34.5) | 11.6(23.2) | 4.3(8.7) | 9.7(19.5) | - | 4.7(9.4) | 8.2(16.5) | - |
| UK-10 | - | - | 3.1(6.1) | 5.7(11.4) | - | 1.0(2.0) | 1.6( 3.3) | - |
| UK-11 | 19.9(39.9) | 19.1(38.1) | 2.8(5.7) | 4.9(9.9) | - | 3.7(7.4) | 4.8( 9.6) | - |

*mg/1

is at a premium. Also, its capacity to handle high concentrations and shock loads of solids is somewhat limited.

The most widely used method for sedimentation of pulp and paper wastes is the mechanically cleaned quiescent sedimentation basin (12). Large circular tanks of concrete construction are normally utilized with rotating sludge scraper mechanisms mounted in the center. Effluent usually enters the tank through a well which is located on a center pier. Settled sludge is raked to a center sump or concentric hopper and is conveyed to further concentration or disposal by solids handling pumps. Floating material is collected by a surface skimmer attached to the rotating mechanism and discharged to a hopper.

At kraft (and NSSC) mills, clarifier diameters range from 9.14 to 106.68 meters (30 to 350 feet) and overflow rates from 15,970 to 82,702 liters per square meter per day (392 to 2030 gallons per square foot per day) overflow. A survey of 12 mills in the five subcategories indicates that the majority of the plants have primary clarifiers with overflow rates ranging from approximately 8148-28,518 liters per square meter per day (200-700 gallons per square foot per day).

A properly designed and installed mechanical clarifier is capable of removing over 95 percent of the settleable suspended solids from all the effluents produced by the subcategories studied. The removal efficiency of this fraction of the total suspended solids is the true measure of performance for this device since it cannot be expected to separate those solids which will not settle under the most favorable conditions. The settleable solids content of linerboard mill effluents average 85 percent of the total suspended solids.

Because of the biodegradable nature of a portion of the settleable solids present in the effluents of these mills, clarification results in some BOD5 reduction. Tabulated data for a number of mills showed a BOD5 reduction effected by settling is less than 20 percent for linerboard mills.

## BOD5 Reduction

BOD5 reduction is generally accomplished by biological means, again because of the relative biodegradability of most of the organic substances in the waste. Lignin is the one major exception. Advances in reduction of internal chemical losses and recycling have removed most of the factors which interfere with biological activity.

While BOD5 reduction by biological methods represents common practice today, it should be understood that other methods discussed under "Color Removal" may, in the future, avoid the need for biological treatment to reduce BOD5.

Common current biological treatment practice is the use of very large storage oxidation basins, aerated stabilization basins, or to a lesser extent, the activated sludge process and modifications thereof. BOD5 reductions of 85-95% are presently being achieved. The aerated stabilization basin is the most widely used method in kraft mill effluent treatment (42). Storage oxidation ponds are used by many mills in conjunction with aerated stabilization basins. The activated sludge process is not used by unbleached kraft mills, and a trickling (roughing) filter is presently being employed by two kraft mills for pretreatment (42). A process flow diagram showing alternate biological effluent treatment systems is shown in Figure 19.

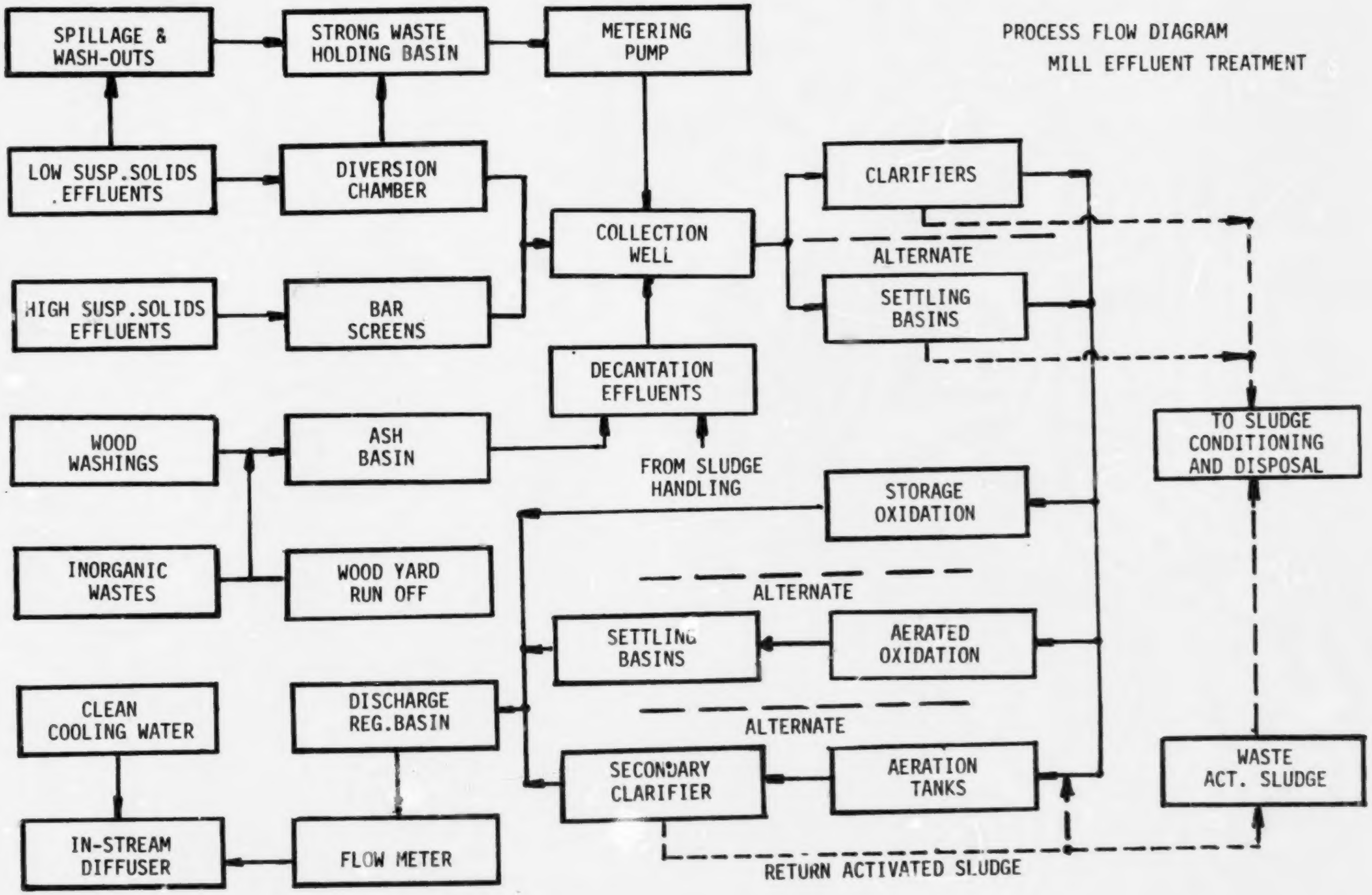
Since the storage oxidation basin is a relatively low-rate process, large land areas are required, making it unsuitable for many locations. Because of the availability of land, and the warmer climate which helps to maintain consistent biological activity, most natural oxidation basins are found in the Southern States (12). Ninety percent BOD5 removal efficiency for an 82-day detention time stabilization basin treating unbleached kraft waste is reported (42). Design loading rates of 56 kilograms BOD5 per hectare per day (50 pounds BOD5 per acre per day) for natural oxidation basins to achieve 85-90 percent removal in warm climates were also reported (43). A survey of four mills with loadings of 59.4 kilograms BOD5 per hectare per day (53 pounds BOD5 per acre per day) or less showed BOD5 removals ranging from 80-93 percent, while basins averaging 112-336 kilograms BOD5 per hectare per day (100-300 pounds BOD5 per acre per day) had removals in the 23-55 percent range. For shallow basins an oxygenation rate of 67.3 kilograms BOD5 per hectare per day (60 pounds BOD5 per acre per day) was reported to be used for design purposes.

By installing aeration equipment in a natural basin, its ability to assimilate BOD5 per unit of surface area is greatly increased. The aerated stabilization basin, as used by all subcategories, originally evolved out of the necessity of increasing performance of existing natural basins due to increasing effluent flows and/or more stringent water quality standards. It soon became apparent that the process had many applications in the pulp and paper industry and, as a consequence, significant use of this waste treatment process began in the early to midsixties.

Due to its inherent acceleration of the biological process, the aerated stabilization basin requires much less land than the natural stabilization basin. Because of the long reaction period, it requires less nutrient addition than that required for activated sludge. Typically, 0.21 hectares per million liters (two acres per MGD) of the aerated stabilization basin compared with 4.8 hectares per million liters (40 acres per MGD) for natural basins for equivalent treatment levels (42). Detention times in the aerated stabilization basin normally range from five to 15 days, averaging about 10 days.

**FIGURE 19**

PROCESS FLOW DIAGRAM
MILL EFFLUENT TREATMENT


SPILLAGE & WASH-OUTS
STRONG WASTE HOLDING BASIN
METERING PUMP
LOW SUSP.SOLIDS .EFFLUENTS
DIVERSION CHAMBER
COLLECTION WELL
CLARIFIERS
ALTERNATE
SETTLING BASINS
HIGH SUSP.SOLIDS EFFLUENTS
BAR SCREENS
DECANTATION EFFLUENTS
WOOD WASHINGS
ASH BASIN
FROM SLUDGE HANDLING
TO SLUDGE CONDITIONING AND DISPOSAL
STORAGE OXIDATION
INORGANIC WASTES
WOOD YARD RUN OFF
ALTERNATE
SETTLING BASINS
AERATED OXIDATION
CLEAN COOLING WATER
DISCHARGE REG.BASIN
ALTERNATE
SECONDARY CLARIFIER
AERATION TANKS
WASTE ACT. SLUDGE
IN-STREAM DIFFUSER
FLOW METER
RETURN ACTIVATED SLUDGE

Due to the relatively long aeration time, the buildup of sludge solids is considerably less than for higher rate processes, particularly where primary clarification is employed. Typical rates are 45.4 to 90.8 grams (0.1 to 0.2 pounds) of sludge generated for each 454 grams (one pound) of $BOD_5$ removed (12). The sludge is removed as formed by endogenous respiration, sludge loss in the effluent, and sedimentation within the aeration basin. However, discharge of untreated waste to an aerated stabilization basin without prior clarification can result in a buildup of sludge which after a period of time will impede its efficiency. An unbleached kraft mill in the study group reported a significant loss in operating efficiency after a period of eight years, at which time approximately 25 percent of the aerated lagoon was filled with sludge. After dredging the sludge, the process returned to a high operating efficiency.

Most mill wastes are deficient in nitrogen and phosphorus. Many of the mills studied found it necessary to add these nutrients to the aeration basin. Nitrogen, in particular, is added in almost every case by mills in four of the subcategories. Reported optimum ratios of $BOD_5$ to nitrogen are 50:1 with four days aeration, and 100:1 with 10-15 days aeration (43).

Aeration is normally accomplished using either gear driven turbine-type aerators, direct-drive axial flow-pump aerators, and, in a few cases, diffused aerators. Oxygenation efficiencies under actual operating conditions range from 0.61 to 1.52 kilograms of oxygen per kilowatt per hour (one to 2.5 pounds of oxygen per horsepower per hour), depending on the type of equipment used, the amount of aeration power per unit lagoon volume, basin configuration, and the biological characteristics of the system. A dissolved oxygen (D.O.) level of 0.5 mg/l remaining in the lagoon liquid is required to sustain aerobic conditions (44). Generally, it was reported that 1.1 to 1.3 kilograms of oxygen per kilogram $BOD_5$ (1.1 to 1.3 pounds oxygen per pound BOD5) are required to maintain adequate D.O. for waste oxidation and endogenous respiration of the biological mass produced.

Although the activated sludge process has been employed for many years to treat domestic sewage, it was first applied to pulp and paper mill waste in 1953 (43). The process is similar to the aerated stabilization basin except that it is much faster, usually designed for four to eight hours of total detention time. The biological mass grown in the aeration tank is settled in a secondary clarifier and returned to the aeration tank, building up a large concentration of active biological material. Since there is approximately 2000-4000 mg/l of active sludge mass in the aeration section of this process, as opposed to 50-200 mg/l in the aerated stabilization basin, dissolved and suspended organic matter are removed much more rapidly, greatly reducing necessary tank volume as well as required detention time. Since biological organisms are in continuous circulation throug out the process, complete mixing and suspension of solids in the aeration basin is required. The active microbial mass consists mainly of bacteria, protozoa, rotifers, fungi, and cyntomnemotodes. Because the process involves intimate contact of organic waste with biological organisms, followed by sedimentation, a high degree of BOD5 and solids removals is obtained.

The contact stabilization process is a variation of activated sludge in that two aeration steps are utilized rather than one. First, the incoming waste is contacted for a short period with active organisms prior to sedimentation. Settled solids are then aerated for a longer period to complete waste assimilation. Contact stabilization has been applied successfully to integrated kraft mill effluent, while conventional activated sludge is used at most other mills.

Activated sludge plants treating pulp and paper waste have been loaded up to 2.41 kilograms of BOD5 per cubic meter (150 pounds of BOD5 per 1000 cubic feet) of aeration tank volume per day (12). Of the mills studied in all subcategories two utilized activated sludge treatment with primary and secondary clarification. In both cases, tank loadings were less than 0.80 kilograms of BOD5 per cubic meter (50 pounds of BOD5 per 1000 cubic feet) with one system operating at less than 0.24 kilograms of BOD5 per cubic meter (15 pounds of BOD5 per 1000 cubic feet). Detention times ranging from 2.5 to 8.5 hours with loading rates ranging from 601 to 2084 kilograms of BOD5 per cubic meter (37.5 to 130 pounds of BOD5 per 1000 cubic feet) have been reported (43). In all cases nitrogen and phosphorus were added.

The secondary clarifier performs the function of sedimentation of the active microbial mass for return to the aeration tank. Rates of about 211 liters per day per square meter (600 gallons per day per square foot) have been reported (42).

Due to the fact that the volume of bio-mass in the activated sludge process is greatly reduced because of hydraulic detention time, the endogenous respiration of the concentrated sludge is considerably lessened. Thus, there are additional quantities of excess sludge, 3/4 kilogram of excess sludge per kilogram of BOD5 (3/4 pound of excess sludge per pound of BOD5), which must be disposed.

As in the case of the aerated stabilization basin, aeration can be accomplished by mechanical or diffused aeration. The more efficient and more easily maintained mechanical method is preferred by the pulp and paper industry. Oxygen requirements where activated sludge processes are utilized were reported in the range of one kilogram of oxygen per kilogram of BOD5 (one pound of oxygen per pound of BOD5) removed.

Short detention times and low volumes make the activated sludge process more susceptible to upset due to shock loads. When the process is disrupted, several days are usually required to return the biological activity and high BOD5 removal rates back to normal. Thus, particular attention is required to avoid such shock loads in mills utilizing this process. The greater shock load tolerance of aerated stabilization basins, lower nutrient requirements, reduced sludge handling problems, and lower cost, explains the general preference for this type of treatment. Exceptions occur particularly where the high cost or unavailability of land dictates the use of the activated sludge process with its much lower land requirement. One such use is in paperboard from waste paper mills located in urban areas. An effluent treatment flow diagram appears in Figure 19.

Trickling filter usage in all subcategories is very limited, primarily due to the inability of such systems to accomplish high degrees of BOD5 removal at high loading levels (43). A kraft mill employing trickling filters with artificial plastic media achieved 50 percent reduction of BOD5 with 50 percent recycle at a loading rate of 80.16 kilograms of BOD5 per cubic meter of media per day (500 pounds of BOD5 per 100 cubic feet of media per day) (43). Another mill indicated that research had shown in order to achieve 50% reduction in BOD5, the loading rate had to be 16 kilograms of BOD5 per cubic meter of media per day (100 pounds of BOD5 per 1000 cubic feet of media per day) (45).

## Two-Stage Biological Treatment

Two-stage biological treatment is employed as an alternative for BOD5 removal obtained with a single stage. This concept consists of two biological treatments systems, usually arranged in series. In the literature (46). a two-stage system is described which employs the activated sludge process in both stages in the treatment of municipal water. The authors note that sludge may be returned or wasted within each stage, or that excess sludge from one stage may be recycled to the other. A principal advantage of this particular arrangement is that the sludge flows may be utilized to maximize BOD5 removal.

Other combinations of biological treatment may be employed in a two-stage arrangment. For example, a trickling filter may precede an aerated stabilization basin or an activated sludge system. This arrangment may be employed where the second stage is required because of insufficient performance of the trickling filter alone. It may also be used in cases where cooling of the waste is required before further biological treatment may proceed. In the latter case, the trickling filter serves as a partial cooling tower, and also accomplishes some BOD5 reduction.

Two-stage aerated stabilization basins, operated in series, may have particular appeal for this industry. This arrangement usually requires less land than a single unit, and can be expected to provide better treatment on an equal-volume basis. For the first stage, a detention time up to two days or more is usually recommended, and up to 10 days or more for the second stage. If sufficient land is available at reasonable cost, this system is usually a less expensive approach than a two-stage system involving activated sludge. It has the further advantage of providing more detention time which is helpful in treating surges of flow or pollutant load. In colder climates, however, arrangements using aerated stabilization basins are more susceptible than activated sludge to decreased wintertime performance. This, in turn, relates to the greater heat loss of the aerated stabilization basin due to its greater detention time as compared to activated sludge. Under conditions of proper design and operation, including nutrient addition and surge basins located prior to biological treatment, BOD5 removals of well over 90 percent can ultimately be expected to be achieved with this system.

A two-stage biological system currently employed by some Southern unbleached kraft mills utilizes an aerated stabilization basin followed by storage oxidation ponds. Typically, detention time of the former is eight to 14 days and for the latter is eight to 60 days. In these installations, overall BOD5 removals (compared to raw waste) of 85-95 percent are being achieved, with 55-70 percent removal after the first stage. These data do not, however, reflect usage of nutrients. It is probable that the addition of surge basins, coupled with nutrient addition, proper aeration and mixing capacity, will ultimately permit BOD5 reductions of well over 90 percent in these systems. For mills with adequate land and other favorable factors, this system may be the most economical approach. The low removal efficiencies in the aerated stabilization basins are considered to be normal practice as historically, the storage oxidation pond was first utilized as the only biological treatment for reduction of pollutants at these mills. As environmental pressures mounted, many mills then installed ASBs as a treatment step prior to the storage oxidation ponds. The ASB's were thus designed as part of a two-stage biological system with reliance upon the storage oxidation pond for further reduction of pollutants. The aerated basins were designed such that the storage oxidation ponds are utilized to further remove BOD5 to the normally accepted secondary treatment removal efficiencies of 85-95% for the total two stage system.

Other combinations of two-stage biological treatment are, of course, possible. These would include use of activated sludge followed by an aerated stabilization basin, storage oxidation, or trickling filters. Such combinations, with rare exceptions, would not usually be the more economical or practicable solution, however.

## Temperature Effects

All biological treatment systems are sensitive to temperature. Optimum temperature for these systems is generally in the 16° to 38°C (60° to 100°F) range. BOD5 removal efficiency is usually lessened as temperature of the waste water drops significantly below or rises significantly above this range.

Temperatures over 38°C may be encountered in warm climates where heat is also added to the waste stream during processing. Cooling towers or trickling filters have been employed to reduce these higher temperatures prior to biological treatment. In colder climates, waste water temperature is likely to drop below 16°C in the winter, particularly where detention time of the biological unit exceeds 12 to 24 hours. With greater detention times, heat loss to atmosphere from the treatment unit generally becomes significant. Thus activated sludge units, which are usually designed for two to 10 hours detention, are less susceptible to reduction of $BOD_5$ removal efficiency in cold climates than are aerated stabilization basins or storage oxidation basins.

The lessened efficiency of $BOD_5$ removal can be mitigated in colder climates by improved design of aeration and mixing factors. Two-stage aerated stabilization basins are likely to perform better in cold temperatures than a single stage of greater total detention time.

## Sludge Dewatering and Disposal

Due to their high organic content, the dewatering and disposal of sludges resulting from the treatment of kraft linerboard can pose a major problem and cost more than the treatment itself. In early practice, these sludges were placed in holding basins from which free water from natural compaction and rainfall was decanted. When a basin was full, it was abandoned, or, if sufficient drying took place, the cake was excavated and dumped on waste land. In this case, the basin was returned to service.

Odor problems from drying, as well as land limitations, have demanded the adoption of more advanced practices. These are covered in detail in NCASI Technical Bulletin No. 190 (47) and are described briefly below.

Depending on the performance of dewatering equipment, in some cases it is either necessary or desirable to prethicken sludges. This is accomplished by gravity thickeners of the "picket-fence" type or by providing a high level of sludge storage capacity in mechanical clarifiers. Small mills sometimes employ high conical tanks which serve as both storage tanks and thickeners. These have side wall slopes in excess of 60° but contain no mechanism.

Vacuum filters are in common use for dewatering sludges from the pulping and papermaking processes considered in this report. They produce cakes ranging from 20 to 30 percent solids. For comparison, filtration rate ranges observed for each subcategory are as shown in Table 28.

TABLE 28

Vacuum Filtration Rates of Sludges

| Product | Dry kg/m2/hr | Dry #/ft2/hr |
|---|---|---|
| Unbleached Kraft | 39 to 93 | 8 to 19 |
| Paperboard from Waste Paper | 10 to 29 | 2 to 6 |
| NSSC | 10 to 64 | 2 to 13 |

Observed capacities for the poorly filterable sludges can generally be about doubled by chemical conditioning with ferric chloride, alum, or polyelectrolytes at a cost of from $2.72 to $4.54 per metric ton ($3.00 to $5.00 per short ton) of dry solids. Such treatment is generally necessary when activated sludge is included in the sludge to be dewatered since the addition of 20 percent of this material on a dry solids basis can reduce filtration rates as much as 50 percent.

Complete vacuum filter installations, including all accessories, range from $4306 to $5382 per square meter of filter area ($400 to $500 per square foot of filter area). Although a number of different types of filters are in service, coil or belt types are the most popular among recent installations. At one mill using coil filters, average cake content of 23 percent was reported, with an influent sludge concentration of 3.3 percent. Loading rates averaged 27.37 kilograms solids per square meter of filter area per day (5.6 pounds solids per square foot of filter area per day). After initial problems, filter availability exceeded 94 percent and cleaning problems were minor (48).

In practice, the higher the consistency of the feed, the more effective centrifuges are in terms of solids capture in relation to through-put as well as to reduced cake moisture. Moisture is generally lower than in cakes produced by vacuum filters. Cakes range from 25 to 35 percent dry solids content and are in a pelletized easily handleable form. To operate effectively, centrifuges must capture in excess of 85 percent of the solids in the feed stream.

Centrifuges cost from $106 to $159 per liter per minute ($400 to $600 per gpm) of feed capacity. At a two percent solids feed consistency, this is equivalent to 97.6 kilograms of dry solids (215 pounds of dry solids) daily at 90 percent capture.

The application of drying beds for dewatering sludges is limited to small mills and they are not constructed as elaborately as are those employed for sanitary sewage. They generally consist only of multiple beds of gravel or cinders without a complex underdrain system.

Detailed experiments on this method of dewatering paperboard mill sludge set forth parameters of good practice and area requirements (49). The latter vary naturally with the climate, although adjustments as to the depth of sludge deposited and its initial moisture content are also involved. The most effective depth is less than one foot.

Sludge can be removed for disposal on the land as soon as it becomes "spadeable" or handleable with earth moving equipment. For paperboard mill sludges, this condition is reached at about 25 percent solids content. Further drying occurs upon the land if initial drying is sufficient.

Some sludges, including those from linerboard mills, can be dewatered to a solids content approaching 40 percent by pressing (50). "V"-type presses are most commonly used but others have proven suitable. First efforts to employ presses involved the handling of sludge cakes obtained from vacuum filtration which contained on the order of 20 percent solids. Recent efforts have been toward direct use of presses on thickened linerboard sludge, thus eliminating the first dewatering step.

Generally, pressing is followed by incineration in air-entrained incinerators which can burn the pressed sludge without supplemental fuel since little further drying is required (51). Semi-chemical corrugating board operations and paperboard from waste paper mills of normal size, however, do not supply enough sludge to support the operation of even a small incinerator. Future developments may permit incineration of sludges from such operations in existing fossil fuel-fired power boilers.

Sludge is also incinerated at some linerboard mills in boilers burning bark or hog fuel. In this case, the pressed sludge is mixed with the bark or fuel before introduction into the furnace (47).

Both types of operation are described in the literature (51) (52) (53), and cost figures are presented. The cost of air-entrained incineration was $14.33 per metric ton ($13 per short ton) and that for burning with hog fuel was $12.68 per metric ton ($11.50 per short ton) of dry solids.

Land disposal, via dumping or lagooning, has been a common means of disposing of waste sludges and other solid wastes from many pulp and paper mills. Odors formed upon decomposition of these materials, the potential for pollution of nearby surface waters, and the elimination of affected lands from potential future usages, have made such practices generally undesirable. If disposed of using proper sanitary landfill techniques however, most solids from the pulp and paper industry should create no environmental problems. In the rare cases where sludges may contain leachable quantities of taste or odor imparting, toxic, or otherwise undesirable substances, simple sanitary landfilling may not be sufficient to protect groundwater quality.

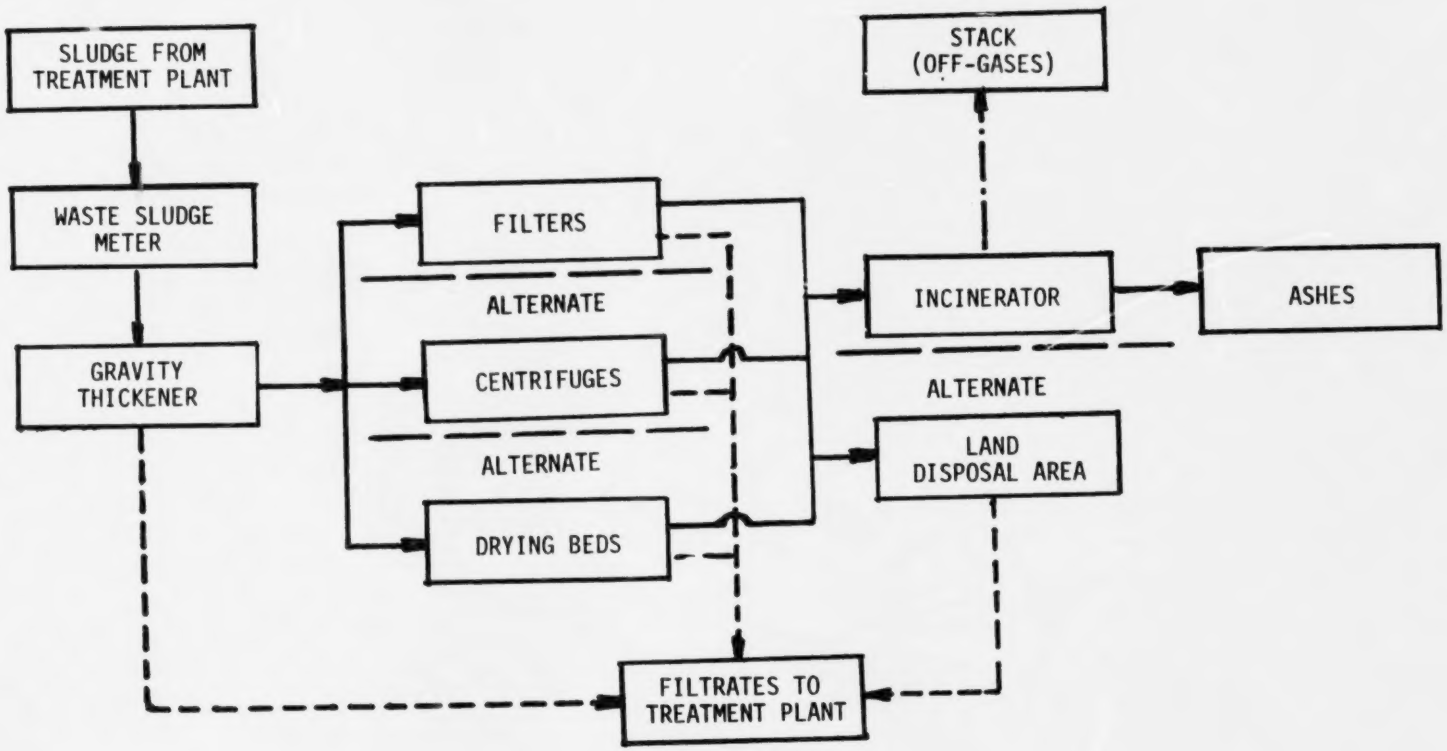
The sludge dewatering and disposal operation is illustrated in Figure 20.

## Byproduct Usage

Interest has been stimulated in utilizing sludge from kraft mills in low grade products such as roofing felts, but lack of uniformity mitigates against such practice. Several researchers (51) experimented with the use of this material as an organic soil supplement and with hydromulching. Incorporation of high sludge levels into soil, after standing for a year, increased bean and corn crops for two successive plantings as compared to control crops. However, equivalent amounts of sludge added to the soil each year caused reduction in crop yields which was apparently due to nitrogen unavailability. In the hydromulching tests in which sludge was applied to a simulated highway cut, sludge with or without the addition of bark dust was found to be competitive with a commercial product for establishing a grass stand.

Several mills are presently experimenting with using the sludge as a soil supplement in reclaiming land for growing pulp wood. Application of primary sludge to the land at loads (dry solids) of 224-448 kkg/hectare (100-200 tons per acre) are being practiced. Cottonwoods are being grown with planned harvest and reapplication of sludge in three to five years following planting.

Interest in production of bacterial protein from cellulosic sludges continues to attract the attention of researchers despite the failure to date of similar products to gain a foothold in the market in this country. A satisfactory product has been produced by growing *thermomonospora fusca*, a strongly cellulolytic thermophylic organism on low lignin pulp mill fines (54). This process is attractive in that acid hydrolysis of the cellulose prior to fermentation is not required. The observed substantial reduction of organic matter which is attained is of considerable interest.


SLUDGE FROM TREATMENT PLANT
WASTE SLUDGE METER
GRAVITY THICKENER
FILTERS
ALTERNATE
CENTRIFUGES
ALTERNATE
DRYING BEDS
STACK (OFF-GASES)
INCINERATOR
ASHES
ALTERNATE
LAND DISPOSAL AREA
FILTRATES TO TREATMENT PLANT

SLUDGE DEWATERING AND DISPOSAL

**FIGURE** 20

## Color Removal

For more than twenty years, the pulp and paper industry has been actively engaged in research for the reduction of color, primarily in kraft mill effluents. The bulk of the research has concentrated on development of lime precipitation techniques because of the relative economics of this compared to other techniques, and the familiarity with and availability of lime handling systems in kraft mills. The overriding initial problem with the lime approaches was the generation of large volumes of gelatinous, difficult to dewater sludges. Several schemes were developed to overcome this problem and full-scale systems have been installed in recent years. Color removal efficiencies of 85 to 90 percent are being achieved. In two unbleached kraft mills, the lime sludge is recovered, dewatered, and incinerated in the lime kiln.

Considerable research has been performed on other color removal techniques, principally activated carbon, reverse osmosis, alum precipitation, resin absorption, ion flotation, ultrafiltration, and amine treatment. Alum precipitation was found to be economical in one instance where alum mud from the nearby manufacture of alum is the primary chemical source. The alum precipitation technique has recently been applied in full scale but a number of operating problems have occurred.

Activated carbon and reverse osmosis have been considered as polishing treatment in conjunction with other processes, for producing a highly treated effluent for discharge. Additionally, they have been considered as a treatment process producing an effluent suitable for recycling. The latter concept appears promising. However, full-scale testing has not yet been completed.

### Sources of Color

In the various chemical pulping processes, lignin and lignin derivatives are solubilized and removed from the wood during the cooking process. The spent cooking liquors, containing these highly colored compounds, are removed from the pulp in a washing sequence following the cooking process. The wash water is highly colored. In the kraft process, however, this wash water is sent to the recovery area, with the exception of the stock decker discharge, where the cooking chemicals are recovered and the organic materials are burned in the recovery furnace. The washing and recovery operations are efficient; however, losses of cooking liquor and the discharge of evaporator condensate and decker filtrate result in a reddish brown effluent. Average values of color discharged from unbleached kraft papermaking operations are shown in Tables 29 and 30 (42).

## TABLE 29

## SOURCES OF COLOR

| Effluent | kg/kkg (lb/ton)* | |
|---|---|---|
| Kraft Pulping | 25-150 | (50-300) |
| Kraft Papermaking | 1.5-4 | (3-8) |

*Based on APHA color units

## TABLE 30

## UNIT PROCESS FLOW AND COLOR DISTRIBUTION IN INDIVIDUAL KRAFT PULPING EFFLUENTS

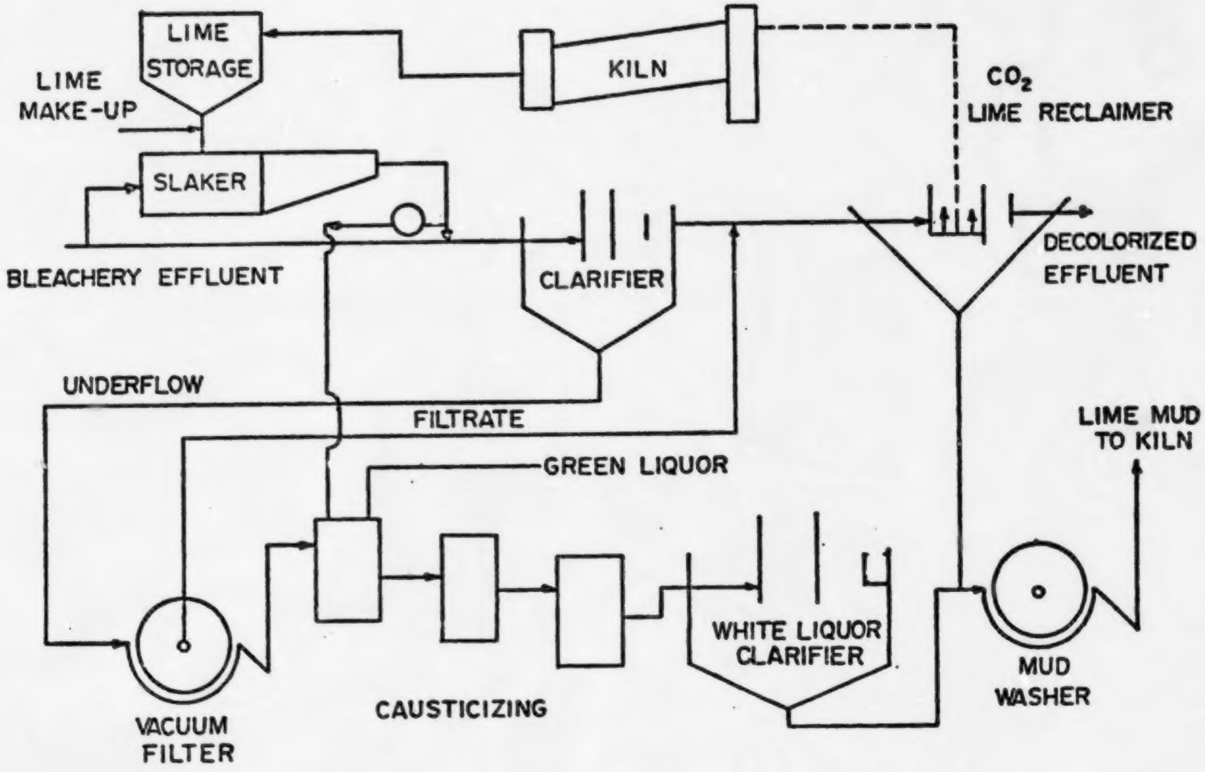
| Unit Process | kiloliters/kkg (1000 gal/ton) | Color Units |
|---|---|---|
| Paper Mill | 47.6 (11.4) | 10 |
| Pulp Mill | 3.8 (0.9) | 520 |
| Evaporators | 0.4 (0.1) | 3760 |
| Recovery | 0.8 (0.2) | 20 |
| Caustic House | 3.3 (0.8) | 20 |

## Lime Treatment

The development of the lime color reduction process has been traced by several authors (12)(42)(55)(56). Based on the results of early work, research was directed towards development of the lime precipitation process with the overriding problem of the difficulty of dewatering the lime-organic sludge. Specific studies were conducted for resolving the sludge problem with limited success (57)(58). Continuing efforts to improve the dewatering of the lime sludge led to consideration of using large dosages of lime for color reduction. In this process (massive lime process), the mill's total process lime is slaked and reacted with a highly colored effluent stream. The lime sludge is then settled, dewatered, and used for causticizing green liquor. During the causticizing process, the color bodies are dissolved in the white liquor and eventually burned in the recovery furnace. Demonstration of the massive lime treatment system for unbleached kraft waste waters has been conducted on a 2000 liters/min (530 gpm) basis (59). Two phases of operation were conducted on unbleached kraft decker effluent. Over 91 percent of the average 1,640 APHA CU were removed during operations which had very little white water reuse in the decker pulp washing operations. When nearly all of the water used in the decker system was white water, the removal efficiency dropped to 74 percent of the initial 900 APHA CU. A flow diagram of the process is shown in Figure 21.

The massive lime process, as developed, relies on high concentrations of lime (on the order of 20,000 mg/l) (60). Because of this, only a relatively small effluent stream could be treated with the quantity of lime used for causticizing green liquor. Additionally, the use of this process required modifications to the recovery system. These restrictions and the need for color removal from total unbleached kraft mill effluents led to the independent development of three lime precipitation processes employing a "minimum" lime dosage for decolorization followed by various methods of sludge disposal or recovery. Two of these systems are now in full-scale operation on the total mill effluent from the production of unbleached kraft pulp (61)(62).

The results of one of the mill's operations show that color is removed from unbleached kraft waste waters under conditions of widely varying raw waste color loads. A relatively constant effluent color of 125-150 APHA CU was obtained independent of influent color levels. The mill influent color levels were generally in the range of 1000-1400 APHA CU. With a lime dosage of 1000 mg/l, removal efficiencies were consistently well above 80 percent. Results of the color removal operations are shown in Table 31 and a flow diagram is shown in Figure 22.


LIME STORAGE
LIME MAKE-UP
KILN
$CO_2$
LIME RECLAIMER
SLAKER
BLEACHERY EFFLUENT
CLARIFIER
DECOLORIZED EFFLUENT
UNDERFLOW
FILTRATE
GREEN LIQUOR
LIME MUD TO KILN
WHITE LIQUOR CLARIFIER
VACUUM FILTER
CAUSTICIZING
MUD WASHER

MASSIVE LIME PROCESS FOR COLOR REMOVAL (9)

FIGURE 21

TABLE 31

Color Reduction by Minimum Lime Treatment

| Month | Data Points | APHA Color Units<br>Influent | Effluent | % Reduction |
|---|---|---|---|---|
| November 1968 | 7 | 1060 | 110 | 88 |
| December 1968 | 1 | 1500 | 150 | 90 |
| January 1969 | 3 | 2100 | 160 | 91 |
| February 1969 | 8 | 2470 | 170 | 91 |
| March 1969 | 12 | 1230 | 105 | 91 |
| April 1969 | 8 | 1300 | 110 | 84 |
| May 1969 | 10 | 690 | 83 | 84 |
| June 1969 | 11 | 1230 | 95 | 90 |
| July 1969 | 13 | 1430 | 110 | 91 |
| August 1969 | 12 | 1150 | 110 | 90 |
| September 1969 | 7 | 1450 | 140 | 90 |
| October 1969 | 12 | 1750 | 135 | 92 |
| November 1969 | 9 | 1690 | 150 | 91 |
| December 1969 | 3 | 1800 | 170 | 90 |
| Averages * | - | 1360 | 120 | 89.5 |

* Weighted averages by number of data points per month.

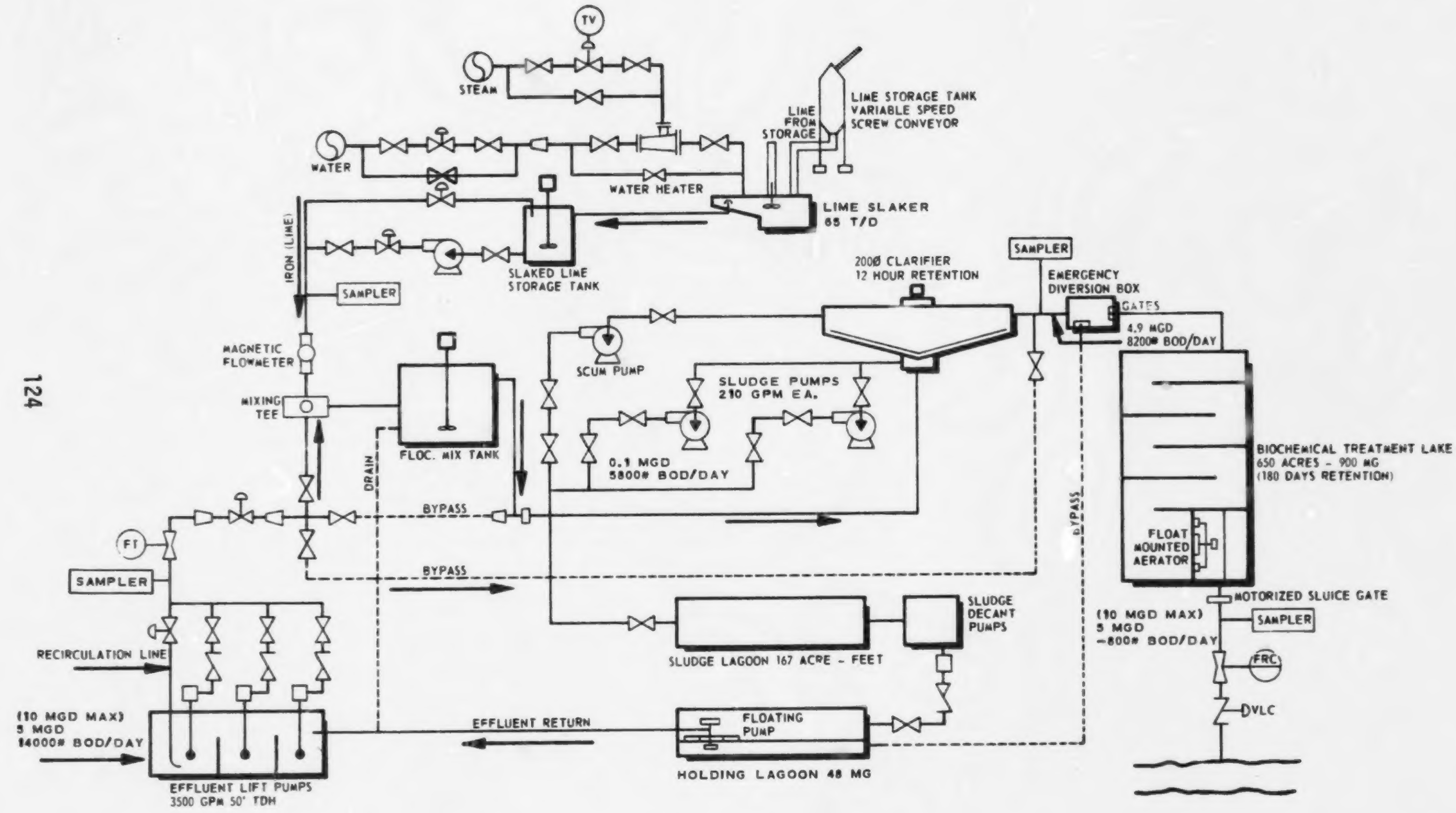

TV
STEAM
WATER
WATER HEATER
LIME FROM STORAGE
LIME STORAGE TANK
VARIABLE SPEED
SCREW CONVEYOR
LIME SLAKER
65 T/D
IRON (LIME)
SLAKED LIME
STORAGE TANK
SAMPLER
MAGNETIC
FLOWMETER
MIXING
TEE
FLOC. MIX TANK
DRAIN
2000 CLARIFIER
12 HOUR RETENTION
SCUM PUMP
SLUDGE PUMPS
210 GPM EA.
0.1 MGD
5800# BOD/DAY
SAMPLER
EMERGENCY
DIVERSION BOX
GATES
4.9 MGD
8200# BOD/DAY
BIOCHEMICAL TREATMENT LAKE
650 ACRES - 900 MG
(180 DAYS RETENTION)
FLOAT
MOUNTED
AERATOR
MOTORIZED SLUICE GATE
(10 MGD MAX)
5 MGD
~800# BOD/DAY
SAMPLER
FRC
DVLC
BYPASS
BYPASS
BYPASS
FT
SAMPLER
RECIRCULATION LINE
(10 MGD MAX)
5 MGD
14000# BOD/DAY
EFFLUENT LIFT PUMPS
3500 GPM 50' TDH
EFFLUENT RETURN
SLUDGE LAGOON 167 ACRE - FEET
SLUDGE
DECANT
PUMPS
FLOATING
PUMP
HOLDING LAGOON 48 MG

Figure 22

Minimum Lime Process for Color Removal (55)

The other full scale installation of the minimum lime process is at an unbleached kraft-NSSC (cross recovery) mill, and the system has been operating for more than two years. As shown in Figure 23, effluent from the mill following grit and trash removal is pumped to a clarifier where approximatey 1000 mg/l of lime is added to the clarifier influent. About 60% of the lime, most of the color bodies, and virtually all of the settleable solids settle to the clarifier bottom. The sludge is removed, thickened by centrifuge, and burned in the mills' lime kiln. The overflow from the clarifier is treated with carbon dioxide using lime kiln stack gas which converts the soluble lime to insoluble lime. The insoluble lime is removed in a second clarifier and also burned in the lime kiln (63).

## Other Color Removal Systems

Although lime treatment methods have been the only color removal processes installed on a full scale basis to date, research is ongoing for other processes. These include activated carbon, reverse osmosis and other membrane techniques, resin separation, ion exchange, and other coagulation systems. Specifically, research into color removal systems for bleached kraft mills which may through further work be applicable to unbleached mills are such systems as resin adsorption, ion flotation, ultrafiltration, and high molecular weight amine purification.

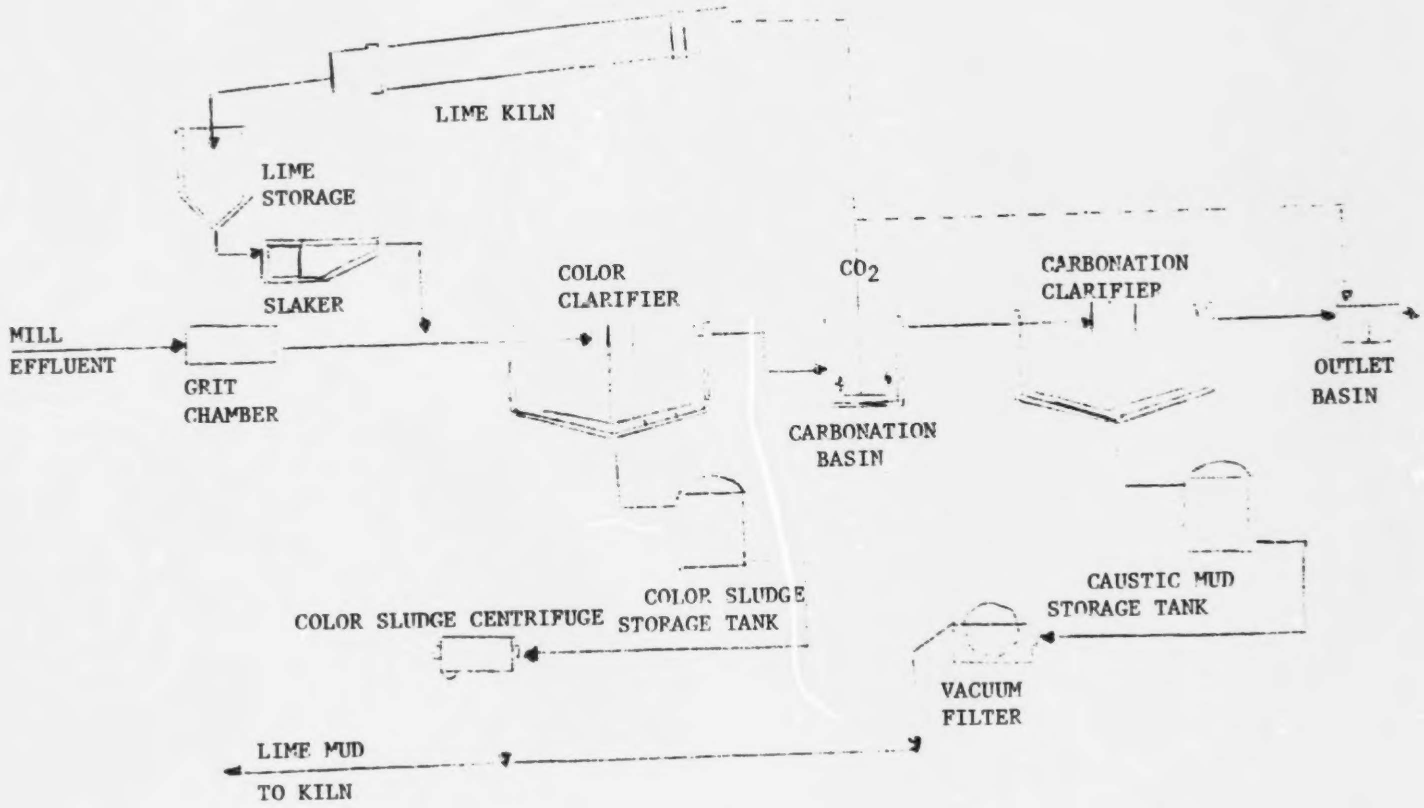
## Coagulation Techniques

The effects of alum and ferric chloride for the removal of color from kraft mill effluents was investigated in the laboratory (64). Tests were run on both hard and softwoods. The optimum dosage of alum on hardwood wastes was found to be 150 mg/l. A color reduction of 89 percent was achieved from an initial color of 710 units. Softwood kraft effluent was found to require a dosage of 300 mg/l. Ferric chloride coagulation of softwood waste required an optimum dosage of 286 mg/l and produced 87 percent removals.

Laboratory investigation was conducted of alum and six organic polyelectrolytes for the removal of color from kraft mill waste water (65). Little difference was reported in the performance of the six polyelectrolytes was reported. Alum produced good results, but resulted in approximately three times the volume of sludge. Color removals averaged 95 percent.

Figure 23

Color Reduction by Minimum Lime With Lime Recovery


LIME KILN
LIME STORAGE
SLAKER
MILL EFFLUENT
GRIT CHAMBER
COLOR CLARIFIER
$CO_2$
CARBONATION CLARIFIER
OUTLET BASIN
CARBONATION BASIN
CAUSTIC MUD STORAGE TANK
COLOR SLUDGE STORAGE TANK
COLOR SLUDGE CENTRIFUGE
VACUUM FILTER
LIME MUD TO KILN

## Activated Carbon

Researchers (42) have reported on the use of activated carbon in combination with other treatment processes on a pilot scale for the treatment of unbleached kraft mill effluent. The treatment sequences were:

1. Primary clarification; activated carbon
2. Lime treatment; clarification; activated carbon
3. Clarification; biological oxidation; activated carbon

The flow diagram of the pilot system is shown in Figure 24. Two carbon systems were evaluated. The first used four standard down-flow columns for series or parallel operation. The second system is called the FACET (Fine Activated Carbon Effluent Treatment) system and is a multi-stage countercurrent, agitated system with continuous countercurrent transfer of both carbon and liquor from stage to stage. It uses a carbon size between standard granular and powdered classifications. The system is the subject of a patent application.

In the lime-carbon system, lime dosages were from 318 to 980 mg/l CaO. The lime-carbon system is referred to by the authors as "micro" lime treatment as compared to the "minimum" lime treatment used by others, (60)(61)(62)(63). With these dosages, the authors state that recarbonation of the effluent is unnecessary for reuse of the treated effluent. It should be noted that the intent of this investigation was to treat the effluent to an extent allowing reuse in the mill. In this respect they were not necessarily looking for a combination of systems capable of producing an effluent suitable for discharge.

Other researchers (66) investigated the efficiency of activated carbon absorption preceded by massive lime treatment, carbonation, and extended aeration in a batch treatment pilot plant. This process was also evaluated without the extended aeration step.

Similiar investigations were also (67) made on a pilot scale. They investigated the effects of massive lime treatment, biological oxidation, and absorption in granular carbon columns. In addition one reacher investigated the effect of activated carbon as a polishing step following biological oxidation and lime treatment. This process was tested on total kraft mill effluent on a semi-pilot plant scale and was also run without the lime treatment step to test the effectiveness of carbon in reducing the effluent color (68).

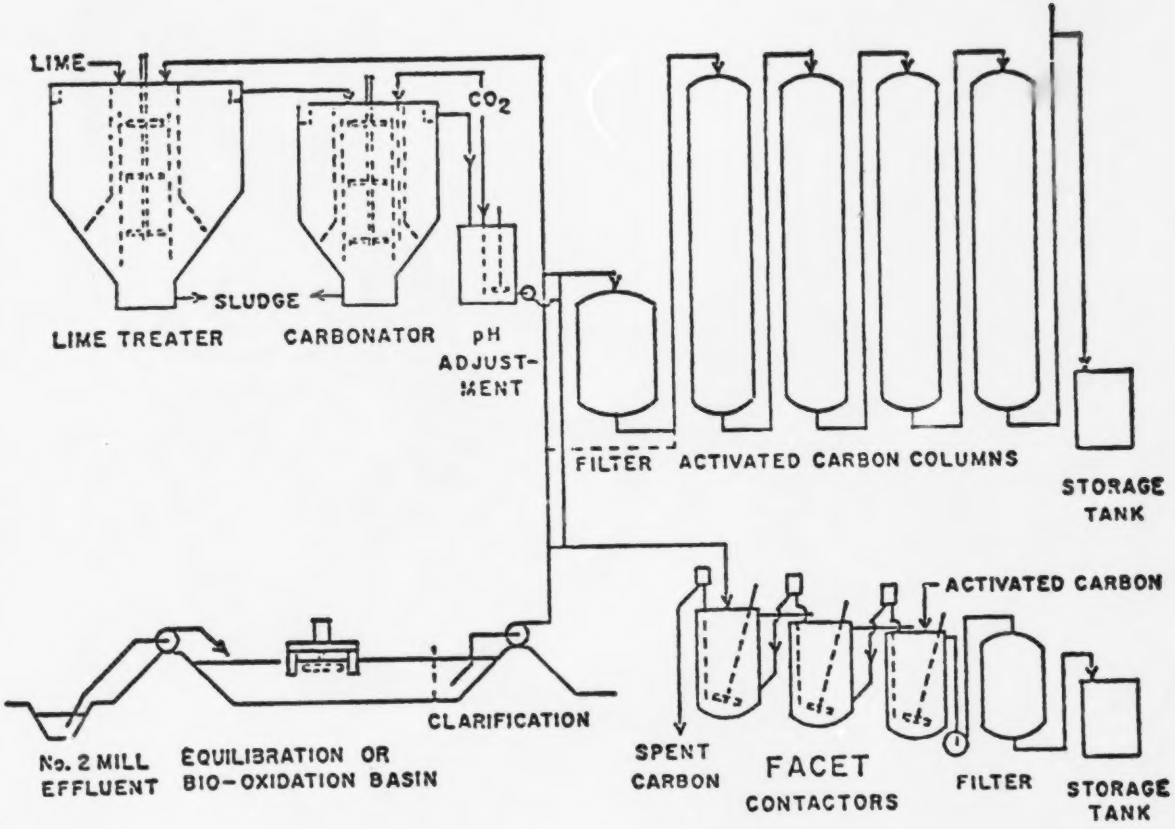

LIME
CO2
SLUDGE
LIME TREATER
CARBONATOR
pH ADJUSTMENT
FILTER
ACTIVATED CARBON COLUMNS
STORAGE TANK
ACTIVATED CARBON
No. 2 MILL EFFLUENT
EQUILIBRATION OR BIO-OXIDATION BASIN
CLARIFICATION
SPENT CARBON
FACET CONTACTORS
FILTER
STORAGE TANK

FIGURE 24

Actived Carbon Pilot Plant

## Comparison of System Efficiencies

It was reported that the biological-carbon treatment sequence utilizing four columns in series reduced color of total kraft effluent to 212 units which they state is too high for reuse in some areas of the mill (42). This is shown in Table 32. It is estimated that an additional three columns would be required to produce the goal of 100 color units.

The primary clarification-carbon system tested used four columns. Color was reduced to 185-202 units. This is shown in Table 33. As with the biological-carbon system, it was estimated that an additional three columns would be required to reach 100 color units.

### TABLE 32

### CARBON ADSORPTION SEQUENCE AT 57 l/min. (15 gpm; 2.3 gpm/ft2)

| | Range | Average |
|---|---|---|
| Feed to bio-oxidation, APHA CU | 430-2500 | 1100 |
| Feed to carbon, APHA CU | 460-1100 | 740 |
| Product from carbon, APHA CU | 42-400 | 212 |
| Removal by bio-oxidation plus filter,% | - | 33 |
| Removal by carbon, % of feed to carbon | - | 71 |
| Total removal % feed to bio-oxidation | - | 81 |
| Rate of removal by carbon, CU/g hr | 0.51-1.00 | 0.77 |

Note: Color measured at pH 7.6 after 0.8 micron Millipore filtration.

### TABLE 33

### COLOR REMOVAL BY PRIMARY CLARIFICATION - CARBON ADSORPTION

| | Trial 1 | Trial 2 |
|---|---|---|
| Flow rate, liters/min(gpm) | 37.8(10) | 18.9(5) |
| Flow rate, liters/min/ft2(gpm/ft2) | 5.4(1.42) | 2.7(0.71) |
| Feed to Carbon, APHA CU | 925 | 11160 |
| Product from Carbon, APHA CU | 185 | 202 |
| Removal by Carbon | 80 | 83 |
| Rate of Removal by Carbon CU/g hr | 0.69 | 0.46 |

Note: Color measured at pH 7.6 after 0.8 micron Millipore filtration.

The clarification-lime-carbon system produced the best results of the three systems. In the lime treatment system, the investigators found that color removal increased from 70 percent at a dissolved Ca concentration of 80 mg/l to 86 percent at a Ca concentration of 400 mg/l. Lime dosages ranged from 318 to 980 mg/l. This reduction is shown graphically in Figure 25. Color removal in the carbon columns (2 columns in series) was also found to be dependent on Ca concentration. Color in the effluent remained at about 60 units at calcium concentrations above 80 mg/l. TOC levels after carbon treatment also varied with Ca concentration, remaining fairly constant with Ca concentrations above 80 mg/l. TOC levels after carbon treatment also varied with Ca concentration, remaining fairly constant with Ca concentrations above 40 mg/l. Color removal through the carbon columns in the soluble calcium range of 69-83 mg/l averaged an additional 21 percent. to give an overall reduction of 90 percent. This is shown in Table 34. Water of this quality was considered suitable for reuse.

Operation of the FACET system following lime treatment produced similar results to the two carbon columns after filtration. This is shown in Table 35.

A total color removal in the four stage (lime - carbonation - oxidation - carbon) system of 99.5 percent was reported (61). In the three - stage system (no oxidation) the total removal was again 99.5 percent. This is shown in Table 36.

As shown in Tables 37 and 38, the color of unbleached kraft effluent was reduced to 10 and 15 units in two separate pilot runs using the massive lime-biological-carbon system. Raw effluent color was 4800 and 3000 units respectively.

### Operation Considerations

It was concluded that the use of a sand filter ahead of the carbon system did not provide enough benefit to warrant consideration in a full-scale installation (69). The investigators also noted concentrated bioactivity in the top one- or two-foot layer of the first column in series which caused plugging. Backwashing was required every one or two days. It was also noted that mechanisms other than adsorption contributed substantially to color removal. This mechanism has been referred to as a coagulation of the colloidal color bodies at the surface of the carbon particle. In the section on "System Efficiencies," it was explained that in the lime-carbon system, lime dosages were recommended to control the dissolved calcium concentration at about 80 mg/l. A benefit of this, as reported, is the elimination of the necessity to carbonate the effluent to remove the calcium. Higher dosages could make carbonation required prior to reuse of the effluent. The lime treatment system also produced a sludge that dewatered readily to 70 percent solids. The authors also state that lime treatment to higher dissolved calcium levels of 400 mg/l followed by carbonation and carbon treatment did not improve color reductions.

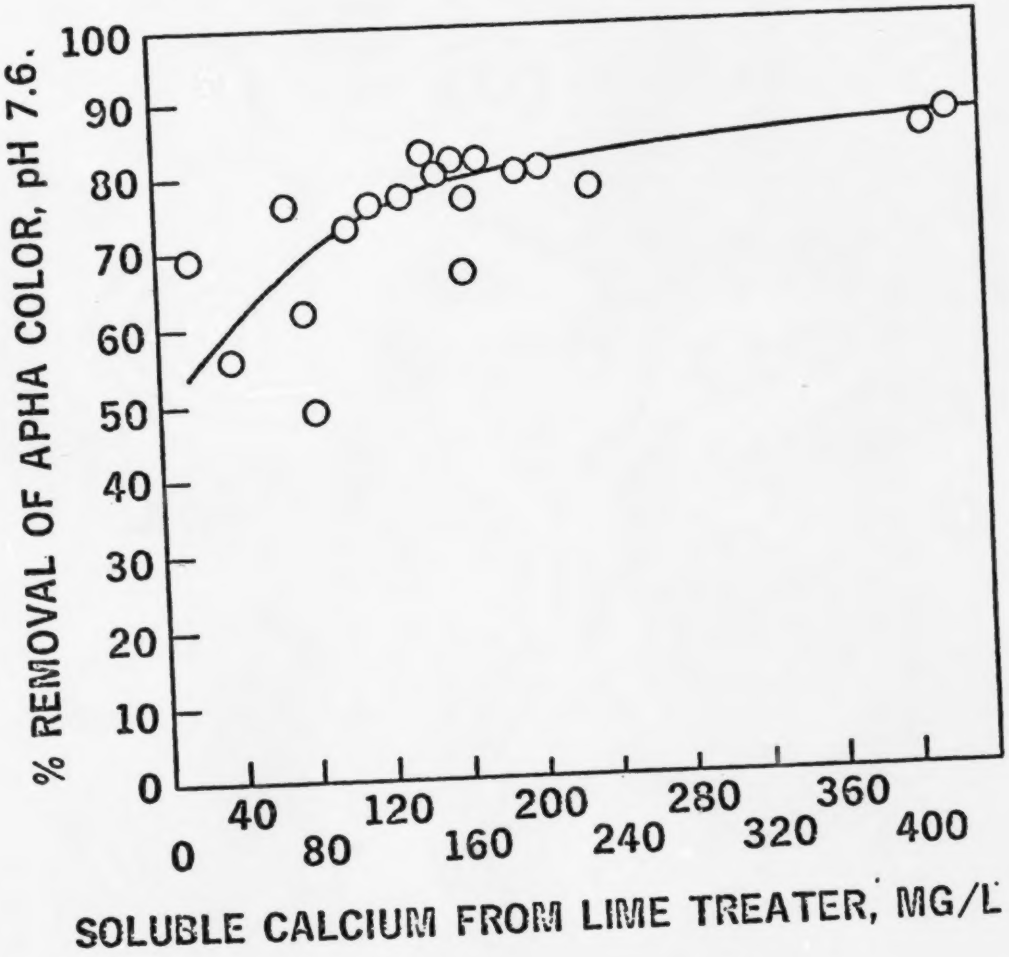


FIGURE 25 COLOR REMOVAL IN LIME TREATMENT AS A FUNCTION OF SOLUBLE Ca IN WATER (74)

## Table 34

## COLOR REMOVAL BY LIME TREATMENT - CARBON ADSORPTION SEQUENCE AT SOLUBLE CALCIUM RANGE OF 69 - 83 mg/1 (29)

| | |
|---|---|
| lime dosage, CaO, mg/1 | 523 |
| pH of feed to carbon adsorption | 11.3 |
| flow rate to carbon adsorption, gpm | 10 |
| No. of carbon columns | 2 |

| Concentrations: | Color, APHA pH 7.6 | TOC, mg/1 |
|---|---|---|
| to lime treatment | 852 | 272 |
| to carbon columns | 252 | 177 |
| from carbon columns | 76 | 100 |
| % removals from feed to lime treatment: | | |
| in lime treatment | 70 | 35 |
| in carbon adsorption | 21 | 28 |
| total | 91 | 63 |

Table 35

## REMOVAL OF COLOR AND TOC BY FACET CARBON ADSORPTION FOLLOWING LIME TREATMENT FOR 12-DAY PERIOD 10/20 THROUGH 11/6 (29)

Conditions:

| | |
|---|---|
| Water feed rate | 10 gpm |
| Carbon feed rate | 2.7 lb/hr = 4.5 lb/1000 gal |
| Carbon in system | 605 lb |
| Carbon slurry density | 14.3 g/100 ml slurry |
| Stages | 3 |

| Removals: | Color, C.U. APHA pH 7.6 | TOC mg/l |
|---|---|---|
| Feed | 157 | 158 |
| Product | 73 | 101 |
| Percent removal | 54 | 36 |
| Removed, mg/g carbon | 214 | 136 |
| Removal rate, mg/g x hr | 0.71 | 0.46 |

## Table 36

### WASTE WATER RENOVATION—SUMMARY OF RESULTS (25)

| Treatment Step | | 5-DAY BOD | | | | COLOR | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Four-stage process | | Three-stage process | | Four-stage process | | Three-stage process | |
| | | mg/liter | % Removal | mg/liter | % Removal | Units | % Removal | Units | % Removal |
| Raw | Max. | 1430 | | 265 | | 12,000 | | 5250 | |
| | Min. | 225 | | 206 | | 1,000 | | 240 | |
| | Avg. | 723 | | 221 | | 5,200 | | 3558 | |
| Lime | Max. | 740 | | 144 | | 1,000 | | 450 | |
| | Min. | 170 | | 69 | | 90 | | 10 | |
| | Avg. | 395 | 45.5 | 102 | 54 | 358 | 93 | 185 | 95 |
| Biol. | Max. | 135 | | | | 1,000 | | | |
| | Min. | 21 | | | | 200 | | | |
| | Avg. | 48 | 88 | | | 365 | 0 | | |
| Carbon | Max. | 80 | | 84 | | 15 | | 55 | |
| | Min. | 0 | | 15 | | 10 | | 0 | |
| | Avg. | 23 | 53 | 32 | 68.5 | 13 | 96.5 | 23 | 87.5 |
| Total | | 23 | 97 | 32 | 85.5 | 13 | 99.5 | 23 | 99.5 |

---

Tests Conducted on Bleached and Unbleached Kraft Effluents.

Table 37

## RENOVATED WATER ANALYSIS (26)

### UNBLEACHED KRAFT LINERBOARD TOTAL MILL EFFLUENT
### PILOT PLANT RUN NO. 1 50 GALLON BATCH OPERATION

| Constituent | Desired Range | Effluent | Obtained by Treatment<br>Lime$^{(a)}$ | <br>Bio$^{(b)}$ | <br>Carbon$^{(c)}$ |
|---|---|---|---|---|---|
| Turbidity, ppm | 5-25 | - | - | 65 | 10 |
| Color, units | 0-80 | 4800 | 140 | 200 | 10 |
| pH | 6.5-7.7 | 8.7 | 11.5 | 9.1 | 8.7 |
| Hardness, ppm $CaCO_3$ | 5-200 | 107 | 7.1 | 86 | 61 |
| Dissolved solids, ppm | 50-500 | 3380 | 2510 | 2650 | 2500 |
| Chloride, ppm | 10-150 | 110 | 140 | 36 | 36 |
| COD, ppm | 0-12 | - | - | 201 | 1 |
| BOD, ppm | 0-5 | 818 | 460 | 8 | 2 |
| Na, ppm | - | 1400 | 1130 | 1600(d) | 1400 |

Notes:
(a) 8.40 lbs, reburned lime slaked and added to raw effluent (equivalent to 20,000 ppm $Ca(OH)_2$).

(b) Extended aeration for 10 days. One gallon fertile lake water added as seed material. $NH_4OH$, $HNO_3$ and $H_3PO_4$ added as nutrient. $H_2SO_4$ added to neutralize.

(c) Carbon columns containing 12x40 mesh activated carbon furnished by Pittsburgh Carbon. Contact time in the carbon bed was 8.2 minutes.

(d) Possible $NH_4^+$ interference.

## Table 38

### RENOVATED WATER ANALYSIS (26)

### UNBLEACHED KRAFT LINERBOARD TOTAL MILL EFFLUENT
### PILOT PLANT RUN NO. 2 50 GALLON BATCH OPERATION

| | | | Obtained by Treatment | | |
|---|---|---|---|---|---|
| Constituent | Desired Range | Effluent | Lime[a] | Bio[b] | Carbon[c] |
| Turbidity, ppm | 5-25 | - | - | - | - |
| Color, units | 0-80 | 3000 | 100 | 200 | 15 |
| pH | 6.5-7.7 | 7.5 | 12.1 | 8.2 | 8.5 |
| Hardness, ppm $CaCO_3$ | 5-200 | - | 964 | 1000 | 866 |
| Dissolved Solids, ppm | 50-500 | 4190 | 2610 | 3070 | 2800 |
| Chloride, ppm | 10-150 | 160 | 200 | 130 | 130 |
| COD, ppm | 0-12 | - | - | - | - |
| BOD, ppm | 0-5 | 1430 | 740 | (135)[d] | (80)[d] |
| Na, ppm | - | 320 | 230 | 230 | 230 |

Notes: (a) 2.87 lbs. reburned lime slaked and added to raw effluent (equivalent to 7500 ppm $Ca\ (OH)_2$).

(b) Extended aeration for 8 days. One gallon fertile lake water added as seed material. $HNO_3$, $H_3PO_4$ added as nutrient. $H_2SO_4$ added to neutralize.

(c) Carbon columns containing 12x40 mesh activated carbon furnished by Pittsburgh Carbon. Contact time in carbon bed was 1.6 minutes.

(d) Estimate, incubator problems.

The authors are enthusiastic about the possibilities of the FACET system. They state that the rate of TOC removal was 4.7 times the rate of removal in columns. Also, the degree of color removal was the same as in the columns, but with one-fifth the amount of carbon. More work is planned. The work performed has been directed towards reuse of the treated effluent. As such, the degree of treatment obtained is less than typical discharge standards. At this time, the effect of recycled effluent on mill processes has not been tested. They are confident the kraft process contains unit processes by which any buildup in contaminants due to recycling can be purged from the system (70).

Others (71) found that elimination of biological oxidation in the lime - carbonation - biological - carbon sequence did not affect color reduction, and $BOD_5$ reduction remained about 85 percent when treating effluents with a moderate raw BOD5. They point towards further research toward improved $BOD_5$ reduction in the lime stage and use of more effective carbons. They also look to requirements for advanced treatments leading to recycle of waste waters and see the possible elimination of biological systems as recycle becomes more important.

## Resin Adsorption

Most research effort on color removal by resin adsorption has been done on bleached kraft effluents. A full scale resin adsorption color removal systems is operating in Sweden at a bleached kraft mill and at least one additional system is being installed at a mill in Japan (72). In addition, pilot scale studies have been conducted at mills in western Canada (73) at an eastern United States mill (74).

The resin adsorption systems do show potential for removal of color from unbleached kraft mills as research is continuing on the application of resin adsorption systems to unbleached kraft mills. However, the resin adsorption systems will not be discussed in detail in this report since most work has been conducted on bleached kraft mills.

## Ion Flotation

The ion flotation technique for removal of color from kraft mill effluents has been operated on a bench scale in western Canada (75). The system basically involves the addition of a surfactant ion of the opposite charge to the ionic species (color bodies) which is to be removed. The surfactant ion combines with the color bodies to form a precipitate which is buoyed to the surface by passage of air through the solution (i.e., dissolved air flotation) and removal of the resulting froth layers removes the color.

The bench scale studies have shown that a very substantial removal of color could be obtained. The optimum color removal conditions were found to exist in the pH range of 3.0 to 5.0 at a surfactant dosage of 500 mg/l. Color removal efficiencies were reported to be over 95% under these conditions.

The ion flotation system shows potential for color removal. However, additional research is necessary into (1) application to unbleached kraft effluents, and (2) techniques to regenerate the surfactant.

## Ultrafiltration

Ultrafiltration techniques for color removal have been investigated on a pilot scale on bleached kraft mill caustic extract effluent and decker effluents (76). Color removals of 90-97% were obtained but plugging of the membrane cartidges was troublesome.

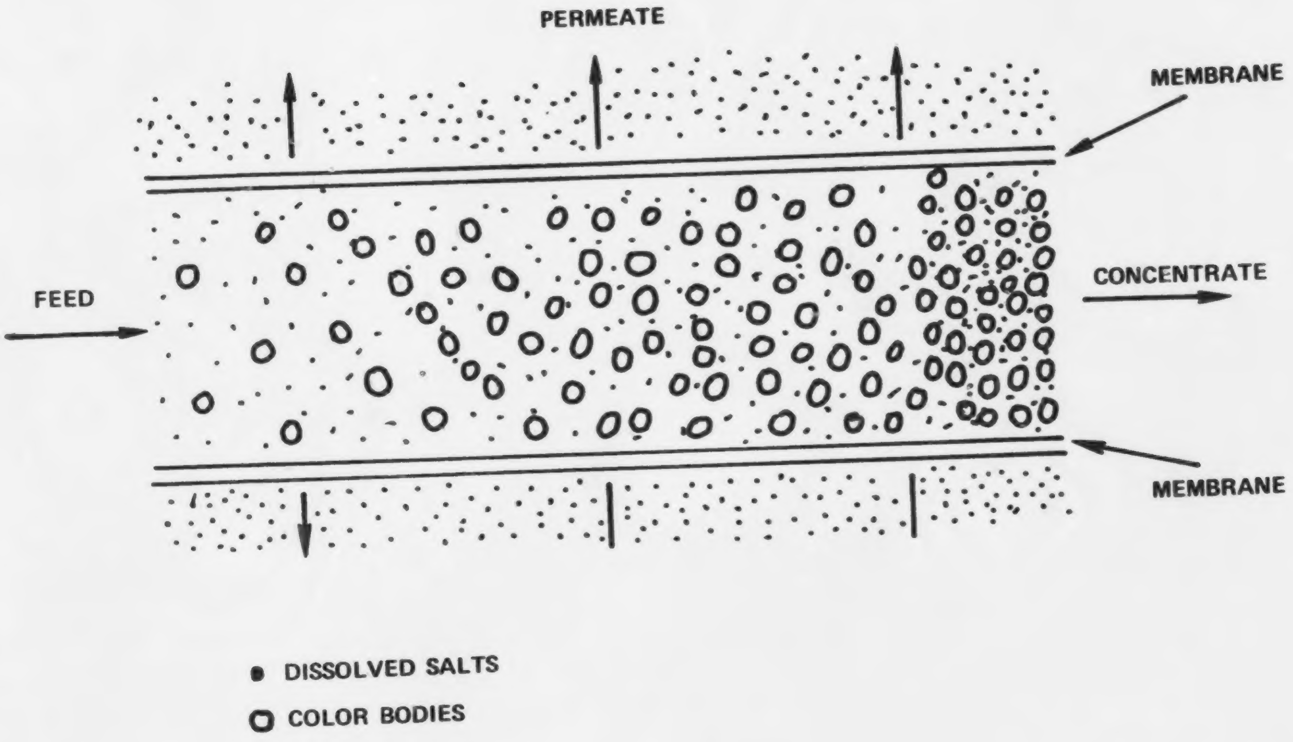
Figure 26 shows the basic ultrafiltration flow schematic. Ultrafiltration is a membrane process and as such is related to reverse osmosis. The ultrafiltration process uses a semi-permeable membrane with an applied hydrostatic pressure as the driving force. The waste water is passed through the membrane, and solutes whose sizes are larger than the membrane pore size are retained and concentrated at the surface of the membrane. The concentrated solutes are removed in solution.

Before full scale application of ultrafiltration, additional research needs to be conducted into the problems of membrane plugging and to determine the long term membrane cartidge life.

## High Molecular Weight Amine Treatment

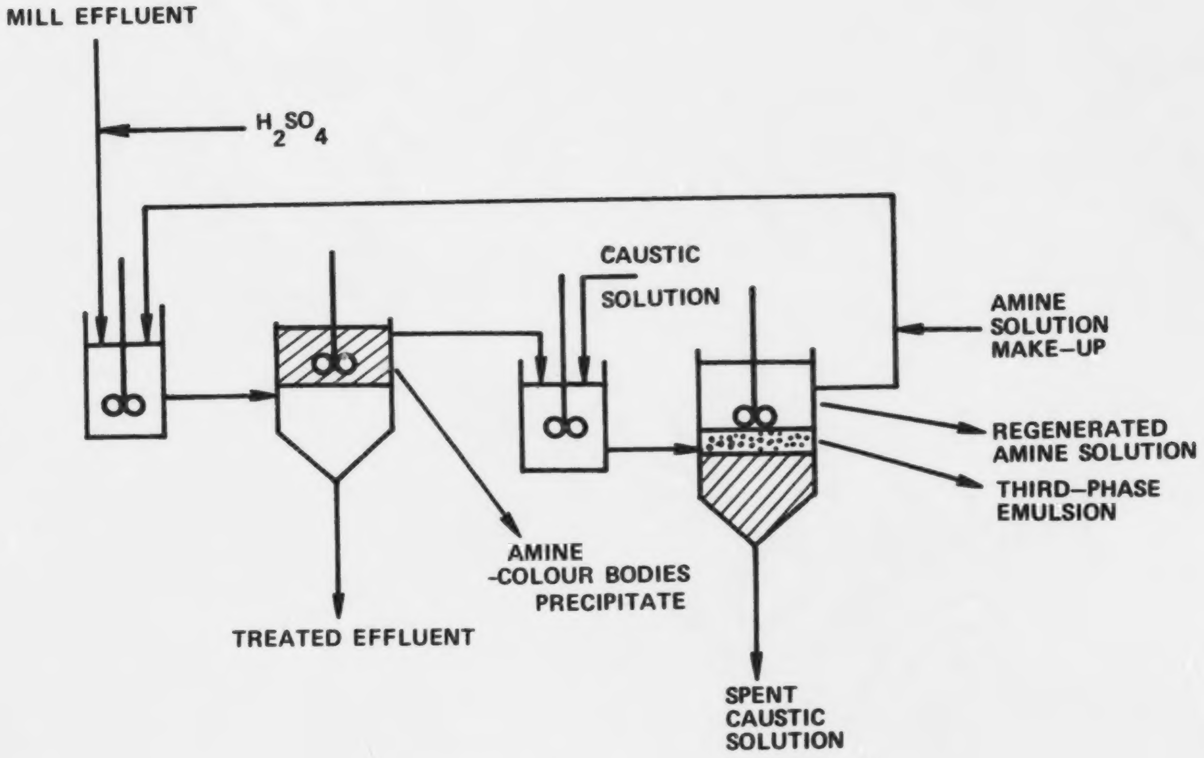
The use of high molecular weight amines for the removal of color from pulp mill effluents was first investigated in France and then more recently in Canada. Amines (in a water-immiscible solvent) have been shown to react with the color bodies in kraft mill effluents and to form a precipitate which can be separated and redissolved in a strong alkaline solution such as white liquor for regeneration of the amine.

Results of bench scale investigations have shown that the amine decolorization technique is capable of removing 90-99% of color from kraft mill effluents. The basic amine treatment process is shown in Figure 27.


PERMEATE
MEMBRANE
FEED
CONCENTRATE
MEMBRANE
● DISSOLVED SALTS
○ COLOR BODIES

SIMPLIFIED ULTRAFILTRATION FLOW SCHEMATIC

Figure 26


MILL EFFLUENT
$H_2SO_4$
CAUSTIC SOLUTION
AMINE SOLUTION MAKE-UP
REGENERATED AMINE SOLUTION
THIRD-PHASE EMULSION
AMINE -COLOUR BODIES PRECIPITATE
TREATED EFFLUENT
SPENT CAUSTIC SOLUTION

SIMPLIFIED AMINE TREATMENT PROCESS FLOW DIAGRAM

Figure 27

## Treatment Systems for Additional Reductions of Suspended Solids and Refractory Organics

Treatment technologies for additional reductions (over those previously discussed) of suspended solids and refractory organics are discussed below.

### Suspended Solids

#### Flocculation, Coagulation, and Sedimentation for Suspended Solids Removal

To avoid rapid plugging of final filters, an additional step to remove suspended solids contained in biological treatment effluents may be required.

Traditional treatment systems have utilized rapid-mix and flocculation basins ahead of sedimentation tanks for chemical clarification. The rapid mix is designed to provide a thorough and complete dispersal of chemical throughout the waste water being treated to insure uniform exposure to pollutants which are to be removed. In-line blenders can be used as well as the traditional high-powered mixers which may require as much as 0.35 kilowatts/MLD (1 horsepower/MGD). In essence, the rapid mix performs two functions, the one previously noted (mixing) and a rapid coagulation. These functions are enhanced by increased turbulence.

Flocculation promotes the contact, coalescence and size increase of coagulated particles. Flocculation devices vary in form, but are generally divided into two categories. These are mechanically mixed and baffled flocculators. Baffled basins have the advantage of low operating and maintenance costs, but they are not normally used because of their space requirement, inability to be easily modified for changing conditions and high head losses. Most installations utilize horizontal or vertical shaft mechanical flocculators which are easily adjusted to changing requirements.

Solids-contact clarifiers have become popular for advanced waste water treatment in recent years because of their inherent size reduction when compared to separate mixing, flocculation and sedimentation basins in series. Their use in water clarification and softening was carried over to waste treatment when chemical treatment of waste waters was initiated. Theoretically, the advantage of reduced size accrues to their ability to maintain a high concentration of previously-formed chemical solids for enhanced orthokinetic flocculation or precipitation and their physical design, whereby three unit processes are combined in one unit. In practice, this amounts to savings in equipment size and capital costs.

Problems have occurred with the sludge-blanket clarifiers for reasons which include possible anaerobic conditions in the slurry, lack of individual process control for the mixing, flocculation and sedimentaiton steps; and uncontrolled blanket upsets under varying hydraulic and organic loading conditions. The major allegation is the instability of the blanket, which has presented operational problems in the chemical treatment of waste waters. Possibly the most effective method of control to date, other than close manual control, has been to mimimize the blanket height to allow for upsets. The advantages of higher flow rates and solids-contacting are maintained, but the added advantage of the blanket is minimized. Another possibility which has not been fully evaluated is the use of sludge-blanket sensors for automatic control of solids wasting.

Solids-contact clarifiers have been used for the treatment of secondary and primary effluents, as well as for the treatment of raw, degritted waste water. Lime as the treatment chemical has been used with overflow rates from 20,400 to 40,700 liters per day per square meter (1200 to 1700 gpd/sq ft) in solids-contact units, while iron compounds and alum have been used at lower values, usually between 48,900 to 69,300 liters per day per square meter (500 and 1000 gpd/sq ft). All of these rates come from pilot studies of less than 3.78 MLD (1 MGD) capacity, and may be subject to change at a larger scale due to differences in hydraulics. Polymer treatment can also influence the choice of overflow rates for design if their cost can be economically justified when compared to the cost of lower overflow rates. Detention times in these solids-contact basins have ranged from just over one to almost five hours. Sludge removal rate is dependent on the solids concentration of the underflow, which is a function of the unit design as well as the chemical employed. These pilot plants have reported lime sludge drawoffs from 0.5 to 1.5 percent of the waste water flow at concentrations of from 3 to 17 percent solids. Alum and iron sludges have not been monitored extensively, but drawoffs have been reported to be 1 to 6 percent of the flow with 0.2 to 1.5 percent solids.

Much of the design information necessary for solids-contact clarifiers has been obtained from water treatment experience. This is not surprising in that the principles of treatment are identical. The characteristics of the solids that are formed and separated are the source of differences. The organic matter contained in the chemically created sludges causes the sludge to become lighter and also more susceptible to septicity due to the action of micro-organisms. The former condition suggests lower hydraulic loadings, while the latter suggests higher ones, given a set physical design. Since sludge septicity is neither universal nor uncontrollable, a lower design overflow rate may comprise much of the necessary adjustment to waste treatment conditions from those of water treatment. As indicated previously, design overflow rates from 48,900 to 69,300 liters per day per square meter (1200 to 1700 gpd/sq ft) for lime treatment and from 20,400 to 40,700 liters per day per square meter (500 to 1000 gpd/sq ft) for alum or iron treatment have been successful at less than 3.78 MLD (1 MGD) capacity. Cold weather peak flow conditions will probably constitute the limiting condition, as water treatment practice has shown that overflow rates are reduced by as much as 50 percent at near-freezing temperature. Wastewater will probably not reach such low temperatures in most areas, but the effects are significant.

## Mixed-Media Filtration

Mixed (multi) media filters are similar to conventional single media deep-bed sand filters, but employ more than one filter media. Typical arrangements employ garnet, sand, or anthracite.

Conventional sand filters have the finer mesh material on top of the bed, with courser grades below. Flow is downward. Thus most of the suspended solids are trapped in the top inch or two of the bed. Certain types of suspended solids, such as those from biological treatment, rapidly plug the top of the bed, requiring very frequent backwashes.

Multi-media filters have been designed with the objective of overcoming this disadvantage of single-media filters. Large size media is employed on the top layer, over a second layer of finer media. Usually anthracite coal is used in the top layer, and sand in the lower layer. Thus larger particles of suspended solids are trapped in the top layer, and finer particles in the lower layer. The result is to extend the filter "run" before backwashing is required. An extension of this principle is to add a third, finer, layer of garnet below the sand layer. Since some intermixing of layers occurs, there tends to be a continuously decreasing particle size of media as depth increases. The different media are selected so that the top bed has the lowest specific gravity, and successively lower beds have successively higher specific gravities. With this arrangemnet, the bed layers tend to maintain their respective physical locations during and after the turbulence created by backwashing. Typical arrangements for dual media filters are anthracite (specific gravity 1.6) over sand (specific gravity 2.65). A layer of garnet (specific gravity 4.2) is imposed below the sand for a three-media filter.

Studies on municipal wastes have indicated that multi-media filters outperform single-media sand filters. Better removal of suspended solids was obtained with longer runs and at higher flow rates per unit area of filter bed.

## Refractory Organics

The advanced waste treatment systems studied for the removal of trace refractory organics include the following: 1) activated carbon, 2) chlorination, and 3) ozonation. The activated carbon process has demonstrated its applicability to the treatment of municipal waste water at full plant scale. Pilot plants and laboratory studies have shown the potential for treatment of pulp and paper mill wastes with activated carbon. However, the potential of the other processes is not well documented and there are no plant scale operations utilizing them. The removal of one specific refractory organic, color, is discussed in detail in a separate subsection.

Activated carbon has been used at water treatment plants to remove organics that caused taste and odor problems in drinking water supplies. The use of activated carbon as a step in the physical-chemical treatment process for domestic waste waters or as an add-on to an existing biological treatment system is well documented (78). Many researchers have studied the use of activated carbon as a tertiary process for the treatment of pulp and paper mill wastes. One of the studies (79) found that activated carbon was capable of reducing color, COD, BOD5, and odor in kraft mill effluents to very low concentrations.

One of the highest concentrations of $BOD_5$ in the whole kraft pulp mill waste discharge is contained in the evaporator condensate (80). Most of the $BOD_5$ and COD of the condensate waste is exerted by dissolved organic material. Several researchers (80) found that 75 percent of the BOD5, COD, and TOD could be removed from the condensates by activated carbon adsorption.

Activated carbon is characterized by an extremely large surface area per unit weight (450-1800 sq. m/g) (69). This large surface area is one feature of activated carbon which results in its large adsorption capacity. It can be separated into two general classifications; powdered and granular. The ultimate adsorption capacities of both powdered and granular carbons are essentially equal (69); however, powdered carbon has faster adsorption rates than granular (81) (82). The number of carbon manufacturers and their particular specifications is very large. The selection of a specific carbon cannot be made, however, without first testing the carbon under consideration with the particular effluent to be treated (83).

The activated carbon process has various configurations which include: use of granular or powdered carbon, contact in a column or slurry, fixed or moving beds, upflow or downflow of influent, series or parallel arrangement, and continuous or periodic wasting and regeneration of spent carbon. Treatability of a particular waste by activated carbon is described by various analytical adsorption isotherm equations which are covered in depth in the literature. The Freundlich equation is probably the most frequently used to determine adsorption isotherm. However, poor correlation between isotherm results and column tests has been reported. This is partially due to the fact that adsorption is not the only mechanism responsible for the removals of organics through carbon columns. Three functions describe the operation of carbon columns (84); adsorption, biological degradation, and filtration.

Most of the researchers studying activated carbon have made one common assumption -- i.e., that the effluent from the carbon system should be of a sufficient quality to permit reuse as process water. According to one study (66), renovated waste water suitable for reuse can be obtained without a biological oxidation step, particularly if the renovation process starts with a moderate BOD$_5$ to 200-300 mg/l. Table 39 presents the pilot plant results obtained by this study.

Other researchers (81) found that adsorption equilibrium increased with a decrease in pH. The effect on the rate of adsorption with changes in temperature is not well defined.

Activated carbon will not remove certain low molecular weight organic substances, particularly methanol, a common constituent of pulping effluents (85). Also, carbon columns do a relatively poor job of removing turbidity and associated organic matter (83). Some highly polar organic molecules such as carbohydrates will not be removed through carbon columns (80) (83). However, most of these materials are biodegradable and would not be present in appreciable quantities in a well bio-oxidized secondary effluent (83).

Results of laboratory rate studies (82) using powdered activated carbon to treat municipal secondary effluents, showed that 90 percent of equilibrium adsorption capacity could be obtained in less than five minutes using turbulent mixing. The researchers considered five different contact systems during their laboratory investigation. The systems considered were:

1. Countercurrent agitated tank adsorption
2. Flotation adsorption
3. Diffusion adsorption
4. Packed bed columnar adsorption
5. Upflow column adsorption

Based on their investigation, the countercurrent agitated tank system was considered as the most promising of the five systems for the following reasons:

1. The secondary effluent did not have to be filtered prior to contact.

2. Variable secondary effluent flow rates and effluent COD concentrations could be readily handled.

3. Maintenance costs were low.

4. Design and operation was simple.

5. The system was truly continuous.

6. COD removals to approximately 5 mg/l could be achieved.

7. The potential existed for treating primary treatment plant effluent.

8. Both suspended solids and colloidal material were brought

## Table 39

### RESULTS OF GRANULAR ACTIVATED CARBON COLUMN PILOT PLANT TREATING UNBLEACHED KRAFT MILL WASTE

| | Columns* Preceded by Lime Precipitation and Biological Oxidation | | | Columns* Preceded by Lime Precipitation | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Influent | Effluent | Removal | Influent | Effluent | Removal | Influent | Effluent | Removal |
| BOD, mg/1 | 48 | 23 | 52% | 102 | 32 | 69% | 82 | 12 | 85% |
| COD, mg/1 | -- | -- | -- | -- | — | — | 320 | 209 | 35% |
| SS, mg/1 | -- | -- | -- | -- | — | — | 115 | 74 | 36% |
| Turbidity, J.U. | -- | -- | -- | -- | — | -- | 35 | 35 | 0% |
| Color, Units | -- | -- | -- | -- | — | — | 28 | 0 | 100% |
| Odor | 365 | 13 | 96% | 185 | 23 | 88% | — | — | — |
| pH | -- | -- | -- | -- | -- | — | 11.9 | 10.5 | 12% |
| T.S. mg/1 | — | — | -- | — | -- | — | 1285 | 1205 | 6% |

*Columns loaded at 3.6 - 4.0 gpm/ft$^2$

down with the carbon due to flocculation.

They reported that the processes investigated for separating the powdered carbon from the treated waste water were not 100 percent effective and filtration of the waste water was necessary to remove the carbon. In a full scale operation, the necessity to filter the effluent might make the use of powdered carbon economically impractical. Other research (80) has showed that 70-75 percent of the organic matter from kraft evaporator condensate could be removed with 0.46 kilograms of carbon per kiloliter (3.8 pounds of carbon per 1000 gallons) of waste water. It was also determined that an extended contact time (over 1 hour) showed insignificant additional COD removal. However, even after six hours of contact there was an effect on the removal of toxicity which was attributed to other various constituents. The results of the work conflict with those reported by others. Other researchers have reported that activated carbon is not effective in removing low molecular weight organics such as methanol and other major constituents of evaporator condensates from the kraft pulping operation. The condensate used by this study may have been contaminated with black liquor carry over.

One research program (69) ran extensive pilot plant tests for treating unbleached kraft mill effluent with activated carbon. Their 114 liter per minute (30 gpm) pilot plant utilized four different treatment processes. They were as follows:

1. Clarification followed by downflow granular carbon columns.
2. Lime treatment and clarification followed by granular carbon columns.
3. Biological oxidation and clarification followed by granular carbon columns.
4. Lime treatment and clarification followed by FACET (Fine Activated Carbon Effluent Treatment). (Subject of a patent application.)

All treatment processes were operated in the attempt to obtain a treated effluent with less than 100 APHA color units and less than 100 mg/l TOC which would be suitable for reuse. The lime-carbon treatment achieved the desired effluent criteria and was considered the most economical of three processes utilizing carbon columns. A relatively small lime dosage of 320-600 mg/l CaO without carbonation prior to carbon treatment was reported to be the optimum operating condition for the lime-carbon process. It should be emphasized that the lack of carbonation was a criterion for optimum treatment. It was determined that the effluent should contain about 80 mg/l Ca for successful optimization of treatment. The required fresh carbon dosage was 0.30 kilograms of carbon per kiloliter (2.5 pounds of carbon per 1000 gallons) treated.

With biological oxidation and clarification followed by carbon columns, the fresh carbon dosage was 0.96 kilograms of carbon per 1000 gallons (8 pounds of carbon per 1000 liters) treated.

It was found that non-adsorptive mechanisms accounted for a significant amount of color and TOC removal in the clarification-carbon process. It was felt that the removals were not due to any biological degradation which might have occurred within the carbon columns. It was determined that the color in colloidal form coagulated on the carbon surface. The color colloids were subsequently removed as large settleable solids during the backwashing process (69). The method of disposal or recycle of the backwash water was not discussed. The disposal of backwash water is a major item and cannot be ignored on full scale designs.

The FACET system is the subject of a patent application (69). It is a multi-stage, countercurrent, agitated system with a continuous transfer of both carbon and liquid. One of the major aspects of the FACET system is the use of an intermediate size carbon endeavoring to combine the advantages of both powdered and granular carbon while minimizing their limitations. Equipment size and carbon inventory are decreased due to the increased adsorption rate of the intermediate carbon. The FACET system showed distinct advantages over the column adsorption system (69). Table 40 tabulates the pilot plant results obtained from the above investigation.

The use of granular activated carbon for the removal of trace refractory organics is technically sound. However, when this degree of treatment is obtained, the ability to reuse the effluent for process water is desirable. Powdered activated carbon has not been widely utilized because of difficult handling problems encountered in carbon recovery and regeneration. It has been reported that the control of pH or temperature, though advantageous to the operation of the process, would be economically impractical (82).

Several others (86) utilized a carbon slurry to treat municipal wastes. They reported a tendency of the compacted slurry in the quiescent concentrator to form a gelatinous mass. It became necessary to agitate the gel to reliquefy it for easy removal.

The use of powdered carbon columns was also studied (82). The researchers found that the columns became clogged with colloidal matter within a few hours of operaton and pressure drops became prohibitive. They tried the upflow contact process, but the bed could not be stabilized and serious channeling occurred resulting in poor COD removal efficiencies. Polyelectrolyte flocculation was determined to be the most economical method of recovering spent powdered carbon. It was also determined that a suspended solids concentration of 500 mg/l or more must be maintained in the carbon slurry to assure flocculation efficiency.

## Table 40

**RESULTS OF ACTIVATED CARBON PILOT PLANTS TREATING UNBLEACHED KRAFT MILL EFFLUENT**

| Description Of Carbon Process | Columns Preceded By Biological Oxidation & Clarification | | | Columns Preceded By Primary Clarification | | | Columns Preceded By Primary Clarification | | | Columns Preceded By Lime Treatment & Clarification | | | FACET System | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Inf. | Eff. | Removal | Inf. | Eff. | Removal | Inf. | Eff. | Removal | Inf. | Eff. | Removal | Inf. | Eff. | Removal |
| Hydraulic Load, gpm/ft$^2$ | 2.13 | | | 1.42 | | | 0.71 | | | 1.42 | | | N.A. | | |
| Carbon | Granular | | | Granular | | | Granular | | | Granular | | | Intermediate | | |
| Contact Time, Min. | 140 | | | | | | | | | 108 | | | | | |
| BOD, mg/l | | | | | | | | | | 26% Removal | | | | | |
| TOC, mg/l | 148 | 57 | 61% | 220 | 83 | 62% | 310 | 121 | 61% | 177 | 100 | 44% | 158 | 101 | 36% |
| Turbidity, J.U. | | | | | | | | | | | 5-15 | | | | |
| Color, Units | 740 | 212 | 71% | 925 | 185 | 80% | 1160 | 202 | 83% | 252 | 76 | 70% | 157 | 73* | 54% |
| Fresh Carbon Dosage lb. carbon/ 1000 gal. | 8 | | | 20.5 | | | 28 | | | 2.5 | | | 3.9 | | |
| pH | | | | | | | | | | 11.3 | | | | | |

*Filtered

Pilot plant tests on domestic secondary effluent were conducted (83) and results showed that organic matter which was adsorbed on the carbon went septic and produced a breakthrough of turbidity and organic matter. An H2S odor in the treated effluent was observed which indicated some biological activity within the first two feet of the carbon column which caused some plugging problems if the columns were not backwashed every day or two. They felt because of the low dissolved oxygen concentration that the biological activity was anaerobic. Chlorination of the influent to the carbon columns appears to eliminate sliming problems caused by biological activity within the columns.

Lower rates of adsorption, were reported (69), resulting in larger projected capital and operating costs, for the biological-carbon and primary-carbon processes for treating unbleached kraft mill effluent. The lower rates of adsorption were believed to be caused by coagulation of colloidal color bodies on the carbon surface. They also determined that the use of sand filters prior to the activated carbon was not necessary. The carbon columns operated with a suspended solids concentration of 200 mg/l without problems when backwashed every day or two. Filtration or coagulation of the effluent from the FACET process was necessary in order to remove that formed on the outer surfaces of the activated carbon granules.

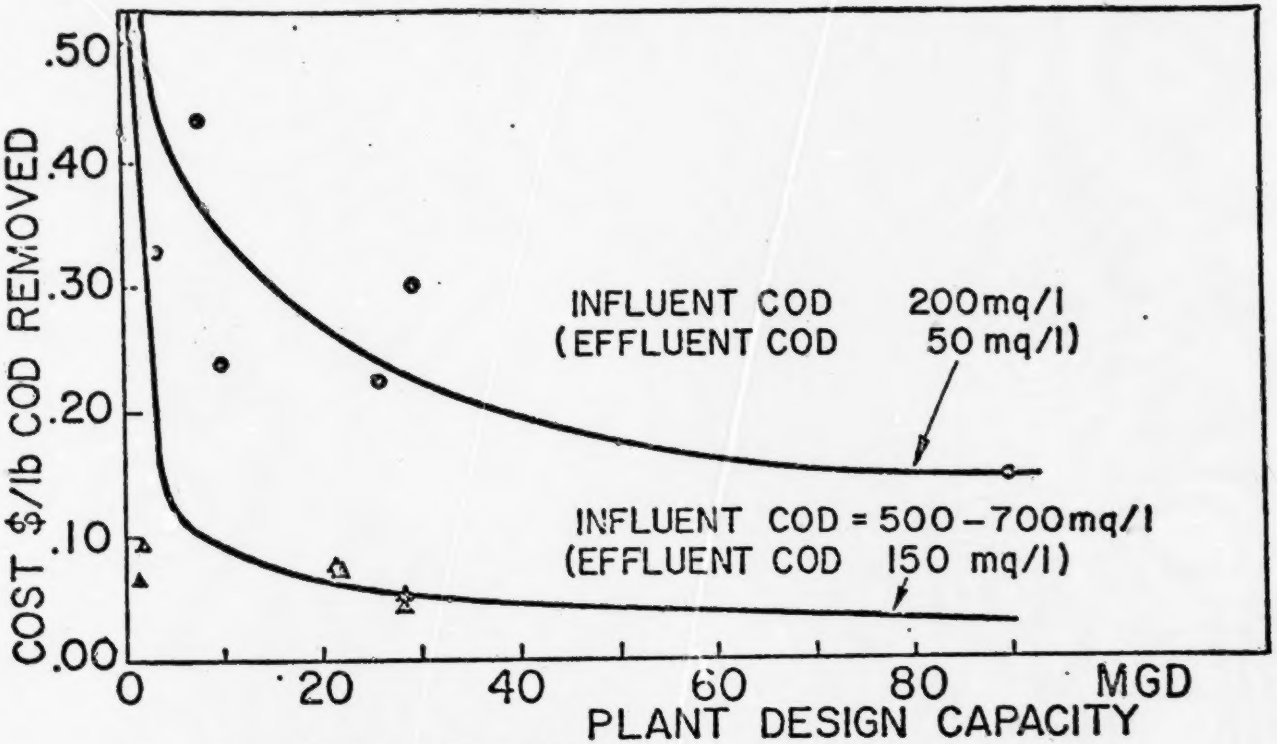
Figure 28 (87) indicates the estimated cost per pound of COD removed for various influent and effluent COD concentrations and various design flows.

Chemical oxidation using chlorine or hypochlorite is an accepted means of disinfection for water supplies and waste water effluents. Chlorination has also been found useful for the removal of ammonia nitrogen and odors from waste water. However, the use of chlorination for the removal of trace refractory organics is not a well-documented process. Several researchers (78) report that the costs indicate that chlorine oxidation is not competitive with activated carbon adsorption for removal of relatively large quantities of COD from municipal wastes. It may offer an alternate for the removal of very small quantities of organics which have not been removed by activated carbon or as a temporary means of reducing the soluble $BOD_5$ in the absence of adsorption equipment. No literature has been found that directs its attention specifically to the applicability of chlorination to the pulp and paper industry. However, a demonstration project has recently been completed on the chlorination of pulp and paper mill effluents and the results should soon be available.

A seven-month study of chlorination was conducted (88) of approximately 303 million liters per day (80 mgd) of effluent from a conventional activated sludge process treating municipal waste water. It was determined that chlorination caused a substantial reduction in the BOD5. The BOD5 decreased an average of 34.5 percent. Very good effluent or effluent from a bulking plant was not significantly improved. Effluent of 12 to 30 mg/l of $BOD_5$ was noticeably improved. The researcher also

**FIGURE** 28

ECONOMY IN SCALE - CARBON ADSORPTION SYSTEMS



1. Costs based on ENR = 1400.

2. Unit costs assume an annual capital recovery factor of 0.0877.

3. Costs include initial carbon inventory, carbon handling system, and regeneration facilities.

monitored the suspended solids, PO4, and TOD. He found that the suspended solids concentration increased about 20 percent. He theorized that some of the soluble compounds were "precipitated" into a suspended state by the chlorine. The PO4 and TOD were not significantly affected by chlorination. Chlorine oxidation, catalyzed with ultraviolet radiation, was studied for the treatment of domestic waste water (89). They found that chlorine will slowly oxidize only a small fraction of dissolved organic material in the dark, but in the presence of ultraviolet radiation, rapid elimination of large amounts of COD and TOC is possible. The most important factor involved in the process was the selection of the source of radiant energy. Short-wavelength radiation (below 300 mu) is more effective than long-wavelength radiation in promoting the chlorine oxidation process. Radiation of 254 mu was about six times more effective than polychromatic radiation between 300-370 mu. The rate of organic oxidation was increased by increased radiation intensity; however, lower intensities produce more overall organic oxidation for a specific amount of absorbed radiant energy than do higher intensities. It was also established that the chlorine consumption was directly proportional to the amount of radiant energy absorbed, regardless of intensity. The effectiveness of treatment is dependent on the penetration achieved by the ultraviolet radiation. However, the correlation of treatment efficiencies with influent color and turbidity concentrations was not reported.

Quantum efficiency is the amount of organic oxidation obtained from a given amount of absorbed radiant energy. Meiners observed higher quantum efficiencies at low intensities and an increase in quantum efficiency as the oxidation proceeded has been observed.

Mercury-arc lamps are the most practical source of radiant energy. However, the ideal mercury-arc lamp is presently not commercially available. Of those presently available, the low pressure mercury-arc is probably the most practical.

The most rapid rate of oxidation and the most efficient use of chlorine was obtained at pH 5. However, the most economic operation may be at ambient pH values without the addition of caustic for pH control.

Chlorine concentrations above 5 mg/l produced no significant increase in the oxidation rate. High concentrations of chlorine were wasteful of chlorine and wasteful of radiant energy. It was concluded that an optimum chlorine concentration below 5 mg/l might be established where oxidation rates could be maximized and chlorine consumption minimized.

Ozone has been used for a number of years at water treatment plants as a deodorant and disinfectant. It has recently been utilized at municipal waste water treatment plants to deodorize gases which are emitted and to disinfect the effluent. Ozone is a very effective disinfectant and oxidizing agent. It is about thirteen times more soluble in water than oxygen. Others (90) have determined that ozone effectively reduces the

COD and TOC content of effluents from municipal waste water treatment plants, as well as odors, color, and pathogenic organisms.

Residual ozone decomposes very rapidly. It has a half-life in drinking water of about 20 minutes. Because of the instability of ozone, it must be produced at its point of use. The most common methods of producing ozone are (90):

1. Silent electric discharge in air or oxygen
2. Photochemical conversion of air or oxygen
3. Electrolysis of sulfuric acid

Photochemical conversion is used only where small quantities in very low concentrations are required. Silent electric discharge is the only practical and economical method for large-scale production of ozone. In general, for large ozone usage, use of oxygen with recycle is a more economical system than using air (90).

Because of the expense involved, the use of ozonation to oxidize organics has not in the past been considered a practical form of tertiary treatment. No investigation of its applicability to the pulp and paper industry has been found.

Laboratory scale tests were conducted (90) with about 37.85 liters per hour (10 gallons per hour) on the use of ozone to oxidize organics remaining in effluent from municipal secondary waste water treatment plants. Effluent from a treatment plant using trickling filters was treated with ozone and virtually all the color, odor, and turbidity were removed. No living organisms remained, and the COD was below 15 mg/l. Ozone concentrations from 11 mg/l to 48 mg/l as oxygen proved equally effective.

Rates of COD and TOC removal were very dependent on agitation rates. Removals were increased approximately twofold using high-shear contacting rather than low-shear countercurrent contacting. Cocurrent contacting, mixing effluent and ozone in an injector, proved more desirable than the use of a turbine agitator. For effective ozonation, good agitation must be considered the prime objective in contractor design (90).

Low pH resulted in lower reaction rates, but higher ozone utilization efficiencies.

Ozone oxidizes many compounds which resist biological oxidation. However, the most readily bio-oxidizable organics also consume ozone the most efficiently (90). Chemical clarification prior to ozonation will remove a portion of the TOC that is resistant to oxidation by ozone resulting in lower final TOC level and less ozone consumption. Ozonation efficiency was high when COD and TOC concentrations were high.

However, the effluent had an unacceptably high COD and TOC content. It was concluded that effluents having high organic content (COD above 40 mg/1) are more economically treated by a combination of chemical clarification and ozonation. Effluents with a low organic content require only ozonation.

Because of the short life of ozone and the slow reaction of ozone with many organics, it was concluded that the best treatment would be achieved with multi-stage, high-shear, gas-liquid contacting. The half-life of ozone is approximately twenty minutes. From this, they determined that a residence time of ten minutes per stage was reasonable. One hour was needed for a COD reduction from 35-40 mg/l to 15 mg/l. Therefore, six stages were necessary. With the required amount of ozone being added to each stage as it was needed, an overall ozone efficiency as high as 90 percent was obtained.

It has been reported (91) that ozonation, catalyzed with activated Raney-Nickel removed 85 percent of the COD and 60 percent of the TOC from secondary treatment effluents in two hours under favorable conditions.

Also, it has been concluded (90) that tertiary treatment with ozone has potential of an automated, trouble-free operation with low maintenance. Initially, they thought that the ammonia in the waste would react with the ozone but found that this was not the case.

The reduction of TOC is caused by organic molecules decomposing and giving off carbon dioxide (90). This rate of decomposition was reduced only at a pH below 7. A lower pH resulted in lower rates of COD removal because the activity of dissolved ozone was enhanced by higher pH. Lime dosage resulted in high pH, while alum-acid coagulants gave the lowest pH. A pH from 6.0 to 7.0 seemed to be optimum for multistage, concurrent ozonation.

## NEUTRAL SULFITE SEMI-CHEMICAL-SODIUM BASE

### Internal Technologies

Water reuse and upset control in this subcategory of mills have been described in detail in the literature (29) (33) (92). The practices of one tightly closed NSSC mill (i.e., with maximum reuse) are illustrative of possible internal modifications to maximize reuse and upset control (33).

The principal direct uses of water in this operation, which consists of an NSSC pulp mill and a closely integrated paper mill, are identified as:

1. Chip cooking
2. Certain fourdrinier showers
3. Pump shaft seals

Indirect uses of fresh water include:

1. Vacuum pump seal coater
2. Losses from indirect steam heating
3. Cooling and condensing systems

Excess white water is used, without treatment, for dilution injection in the digesters and in the screw presses used for separation of strong cooking liquor prior to evaporation and burning.

During daily wood pulp production of 181.4 metric tons (200 short tons), some 90,800 kilograms (200,000 pounds) of dissolved solids are produced. Approximately, 68,100 kilograms (150,000 pounds) of this amount are removed in the combined screw pressate and digester blow liquors, reduced to 21 percent solids by indirect evaporation, and supplied to the fluidized bed reactor. Additional solubles are introduced into the overall system via the 86.2 metric tons (95 short tons) of waste paper utilized daily.

The remaining soluble solids remain with the pulp as it proceeds to the stock preparation/papermaking system. Routinely a high percentage of these solubles remains with the paperboard as manufactured, but two principal sewer losses occur. One is "carryover" into the vacuum pump seal water. The other represents non-equilibrium losses due to shut-downs, equipment failures, and other factors mentioned in the above sub-section on unbleached kraft mills.

Emphasis is placed on controlling the effects of these non-equilibrium upsets. These efforts include:

1. Prevention of spills by process control modifications.

2. Redirection of overflow pipes to trenches leading to "contaminated" surge vessels for ultimate reuse.

3. Individual revisions of level controls and storage tanks to minimize overflows and spills.

4. Redundant installation of key pumps and other equipment to avoid losses due to equipment failure and routine maintenance.

5. Monitoring systems to alert operating personnel of potential and actual spills so that corrective action can be promptly initiated.

6. Storage lagoons located prior to biological treatment may be provided to accept longer term shock loads.

7. Personnel should be trained to avoid such spills where possible, and to take immediate corrective action when they occur.

It will be recognized that most of these techniques are the same in principle, if not in detail, as those in-plant measures applicable to unbleached kraft mills.

From the engineering viewpoint, it is readily evident that none of the above measures represent novel technology. What is novel, however, is the "systems approach" to a complex manufacturing operation having variables and potential loss points measured in the hundreds or even thousands. This kind of effort, however, is necessary and recommended to effect a significant reduction in raw waste loads, particularly surge loads, with their adverse impact upon external treatment facilities and final effluent quality.

One mill may soon install a reverse osmosis system to handle unavoidable final spills (93). For this system to operate economically it is imperative to reduce the volume of waste water to be treated. While this program will not result in zero discharge of pollutants, it is expected that very significant reductions, over and above those itemized above, will occur.

Another mill (29) has applied similar techniques in reuse of white water, but has taken a different approach in disposal of spent NSSC liquor. As in the above case, intensive reuse results in white water characteristics approaching those of the spent liquor itself. For example, white water solubles approach the three to four percent figure in both mills. Since both mills make corrugating medium, the corresponding levels of solubles (primarily spent cooking liquor) can be tolerated in the end product. This is not true of many other subcategory grades.

Problems occur with increased reuse as discussed in the subsection above. An NSSC mill (29) has delineated these problems as process water usage approached 6260 liters/kkg (1500 gal/ton):

1. Variable paper quality due to wet streaks in wet felts
2. Decreased wet felt life due to plugging from fines
3. Increased slime deposits
4. Higher maintenance costs due to increased cleaning of machine elements
5. Higher corrosion rates
6. Increased calcium scaling
7. Greater chemical demands for sized and wet strength grades
8. Buildup of contaminants from waste paper
9. Increased incidence of sheet breaks, particularly at the presses, due to "stickiness" caused by solubles buildup and to apparent reduction in wet web strength

To minimize the above problems, fresh water usage was increased to 8346 liters/kkg (2000 gal/ton) from 6260 liters/kkg (1500 gal/ton).

The techniques and methods of internal controls for the stock preparation and paper machine operations as described for unbleached kraft mills are equally applicable to this subcategory.

## External Technologies

Although there are variations in concentrations and specific waste constituents, the general classes of compounds which occur in these wastes are similar to those occurring in unbleached kraft wastes. Thus, treatability and treatment systems for NSSC-sodium are similar to the systems discussed previously in unbleached kraft. Specifically, the discussions of suspended solids removal and $BOD_5$ removal apply to NSSC-sodium mills also. Data on two NSSC sodium base mills which have secondary treatment and for which secondary treatment effluent data were available are shown in Tables 41 and 42. Specifically, Table 41 shows production, flow, type of treatment, and the TSS analytical measurement technique for each mill. Table 42 shows $BOD_5$ and TSS data for the mills' raw waste and final effluents (Note: AA is the annual average of daily values and MM is the maximum monthly average of daily values). The data generally represent a full year's operation and have been derived from mill records by either EPA or the NCASI.

As shown in Table 24, color removal techniques on NSSC waste waters primarily include reverse osmosis. Reverse osmosis has been extensively investigated for possible application within the pulp and paper

## TABLE 41

## MILL DATA

## NSSC - SODIUM BASE

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment Detention (Days) ASB | Treatment Detention (Days) SO | Aeration in HP ASB | TSS Methods |
|---|---|---|---|---|---|---|
| NS-1 | 336(370) | 44.6(10.7) | 3 | 14 | 515 | SM |
| NS-2 | 521(574) | 48.8(11.7) | 5* | 0 | 1200 | SM |

* Clarifier-ASB-Clarifier return sludge

TABLE 42

MILL EFFLUENT DATA

NSSC - SODIUM BASE
(All values in kg/kkg (lbs/ton) except as noted)

| | Raw Waste | | Final Effluent | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mill | AA BOD5 | AA TSS | AA BOD5 | MM BOD5 | MM BOD5* | AA TSS | MM TSS | MM TSS* |
| NS-1 | 8.5(17) | 8.5(17) | 0.75(1.5) | 1.3(2.7) | - | 1.6(3.2) | 3.2(6.5) | - |
| NS-2 | 31(62) | 17.5(35) | 3.2(6.4) | 4.3(8.7) | 97 | 13.3(26.6) | 18.7(37.5) | 424 |

*mg/1

industry. All of the work, however, has been undertaken on a pilot plant basis. The progress made with reverse osmosis systems within the past five years suggests that it could in the future be a very valuable tool in waste treatment for removal of color and suspended and total dissolved solids. At present this method seems particularly applicable to NSSC mills. While many of the mechanical problems have been solved, membrane life and flux rates have not progressed to the extent where large scale applications can be considered. If membrane life can be improved and flux rates increased, then the total costs could be lowered.

The initial work with membranes was in conjunction with an electrodialysis system (94). Electrodialysis investigations of pulp liquors provided important background on new membrane processes such as ultrafiltration and reverse osmosis. The application of reverse osmosis membranes has been centered on concentrations of dilute streams in the range of one-half to one percent suspended solids (95) (96).

The Pulp Manufacturers Research League and The Institute of Paper Chemistry have investigated the reverse osmosis process for treatment of pulp and paper mill waste waters under a project partially sponsored by the Office of Research and Monitoring of the Environmental Protection Agency (94). Their studies led to confirming trials conducted in field demonstrations ranging from 18,900 to 189,300 liters per day (500 to 50,000 gallons per day) on five different waste flows. The five field demonstrations were undertaken on:

1. Ca Base Pulp Washing and Cooling Waters
2. NSSC White Water
3. NH3 Base Pulp Wash Water (also Calcium Hypochlorite Bleach Effluent)
4. Kraft Bleach Effluent (also Kraft Rewash Water)
5. Chemi-mechanical Pulping Wash Water

Their study concluded that the reverse osmosis process is an important new tool for concentrating and recovering solutes in dilute pulp and papermaking effluents (94). They obtained membrane rejections of 90 to 99 percent for most components in the feed with the exception of low molecular weight salts and volatiles which were less well rejected.

One mill has also undertaken detailed studies for the use of reverse osmosis as a unit operation for producing water suitable for process reuse under a program also partially funded by the Office of Research and Monitoring of the Environmental Protection Agency (95). This study included the operation of proprietary osmosis equipment on a pilot basis by vendors simultaneously and continuously on the same feed. This allowed the development of operating techniques applicable to the particular feed and development of design criteria for the design of a full scale production facility. This study also concluded that the reverse osmosis process is effective in concentrating the dilute waste stream while producing a clarified water flow that can be recycled for process purposes (93). The concentrated stream would be directed to the fluidized bed reactor operating as part of their chemical recovery system. Three basic types of reverse osmosis membrane surfaces are available:

1. Capillary fiber
2. Sheet membrane (spiral round)
3. Tubular

Tubular membranes have been found to be the most suitable in the work that has been undertaken because capillary fiber and sheet membranes were more subject to clogging problems (96). Most of the work with reverse osmosis has been concerned with the use of cellulose acetate membranes, but some work with dynamic membranes, or replaceable membranes, is receiving more attention as it could substantially reduce the cost of reverse osmosis systems (94) (97).

The reverse osmosis process would best fit into a treatment scheme following primary treatment, prior to activated carbon polishing if the benefits derived from the improved solids removal and the elimination of pretreatment with massive lime and large scale activated carbon are greater than the incurred loss of membrane capacity resulting from lower flux rates (98). While hyperfiltration is very effective in removing color and macromolecular organic compounds, certain lower weight molecular organic compounds are not rejected by the reverse osmosis process.

If color removal only is necessary, the ultrafiltration as described previously which is not as effective as hyperfiltration in removal of organic matters and solids, but is very effective in color removal, would be satisfactory (97).

The efficiency of the reverse osmosis process for NSSC pulp and papermaking waste waters is presented in Table 43 (96).

The waste flows had to be pretreated by passage through a 40 mesh screen and the temperature adjusted to a safe operating range to protect the cellulose acetate membranes (below 40°C) (96).

The extensive pilot testing undertaken by a sodium base NSSC mill showed general rejections by the reverse osmosis process as follows (94):

| | |
|---|---|
| Total Solids | 99.7% |
| $BOD_5$ | 98.6% |
| Color-Optical Comparator | 99.6% |
| Color-Spectrophotometer | 99.8% |

The work by the Institute of Paper Chemistry indicated that fouling of reverse osmosis membranes by suspended particles, colloidal suspensoids

## TABLE 43

SUMMARY OF RESULTS OF TREATMENT BY REVERSE OSMOSIS (77)

| | REPORTED REJECTION - % | | | | | |
|---|---|---|---|---|---|---|
| WASTE FLOW | TOTAL SOLIDS | BOD | COD | BASE | COLOR | WATER RECOVERY |
| Calcium Sulfite | 87-98 | 69-89 | 87-95 | 95-99Ca | 99 | 80-90 |
| NSSC | 96-98 | 87-95 | 96-98 | 82-95Na | 99+ | 72-92 |
| Ammonium Sulfite | 93-96 | 77-94 | 92-97 | 92-98$NH_3$ | 99 | 65 |
| Kraft Bleach | 91-99 | 85-97 | 97-99 | 83-95Na | 99+ | -- |

of large molecular weight organics, etc., could be partially controlled by pretreatment, by periodic pressure pulsations, and by periodic washing of the membrane surfaces (95). Self-cleaning, high velocities of flow were found to be the most likely means of maintaining high flux rates through the membrane, especially with the newer high performance, tight surface membranes that became available in 1971. It was reported that minimum velocities of 0.61 meters per second (2 feet per second) overcame concentrative polarization, but 0.91 meters per second (3.0 feet per second) were required to maintain adequate mass transfer rates (95). It was also stated that concentracion polarization did not appear to seriously affect performance at operating pressures below 55.4 atm. (800 psig).

Present commercial hyperfiltration membranes cannot be operated at temperatures much above ambient, and cooling of many pulping effluents is therefore necessary. Dynamically formed membranes, however, have been shown to suffer less from these disadvantages and may be preferable when a high degree of salt removal is not required (97). In addition, ultrafiltration membranes are more open than the more tight reverse osmosis (hyperfiltration) membranes and while rejection for colored ligonsulfonates is high, other components are rejected to a much less satisfactory degree. Research is being carried out to develop improved rejection with ultrafiltration membranes because they have higher flux rates than hyperfiltration and the advantages of simplified equipment design (94). In addition, a major roadblock delaying the practical use of reverse osmosis in waste treatment lies in the several causes of short life expectancy in the membrane system. Membrane manufacturers should be encouraged to obtain goals of a minimum three-year life expectancy for these membranes (96). In addition, membrane development should include a capability for operating at wider ranges of pH and temperature (96) and higher flux rates.

Dynamic membrane studies should be advanced to achieve higher levels of solid rejection without serious reduction in permeate rates and flux rates. The development of these membranes could substantially improve performance and cost parameters (64) (97) (99).

## NSSC-AMMONIA BASE

### Internal Technologies

Ammonia base and sodium base NSSC pulping are separate subcategories in that the two bases produce different waste characteristics. However, they are essentially the same process in terms of equipment used and the manufacturing steps involved, with the exception of spent liquor handling in some cases. Therefore, the sources of waste water would generally vary only as they typically vary from mill to mill without a subcategory, and, thus, offer a potential for water reuse similar to that described above for sodium base mills. Ammonia base mills, however, have experienced somewhat more difficulty in reduction of waste flow volume through reuse because of the buildup of ammonia within the process system.

The techniques and methods for reducing upset and spills described for both the unbleached kraft and sodium base NSSC mills, or some modification of them, are equally applicable to this subcategory. In the newest mill of this type, there are only two in operation, design efforts are underway to eliminate a waste stream which contributes about 18-20 percent of the total raw $BOD_5$ load of the mill. This is from the screwfeeder utilized to press water from the chips before the digester to achieve a sufficiently high dry solids content.

The additional internal control needed in this type of mill is one which will reduce ammonia concentrations in the waste stream. One proposal is to channel the primary cooling water into the weak black liquor as it enters the evaporators (100), thus lowering the pH and inhibiting conversion of ammonium to ammonia. The techniques and methods of internal controls for the stock preparation and paper machine operations as described for unbleached kraft mills are equally applicable to this subcategory.

### External Technologies

Although there are variations in concentrations and specific waste constituents, the general classes of compounds which occur in these wastes are similar to those occurring in unbleached kraft wastes. Thus, treatability and treatment systems for NSSC- ammonia are similar to the systems discussed previously in unbleached kraft. Specifically, the discussions of suspended solids removal and $BOD_5$ removal apply to NSSC-ammonia mills also. Data on one NSSC ammonia base mill which has secondary treatment and for which secondary treatment effluent data were available is shown in Tables 44 and 45. Specifically, Table 44 shows production, flow, type of treatment, and the TSS analytical measurement technique for the mill. Table 45 shows $BOD_5$ and TSS data for the mills' raw waste and final effluents (Note: AA is the annual average of daily values and MM is the maximum monthly average of daily values). The data represent a full year's operation and have been derived from mill

### TABLE 44

### MILL DATA

### NSSC - Ammonia Base

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment Detention (Days) ASB | SO | Aeration in HP ASB | TSS Method |
|---|---|---|---|---|---|---|
| N-1 | 390 (430) | 32.5 (7.8) | 12 | 3-14 | 500 | NSM |

TABLE 45

MILL EFFLUENT DATA

NSSC - Ammonia Base
(All values in kg/kkg(lbs/ton) except as noted)

|  | Raw Waste |  | Final Effluent |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Mill | AA<br>BOD5 | AA<br>TSS | AA<br>BOD5 | MM<br>BOD5 | MM<br>BOD5* | AA<br>TSS | MM<br>TSS | MM<br>TSS* |
| N-1 | 33.7(67.5) | 17(34) | 5.8(11.7) | 13.1(26.3) | 335 | 4.2(8.5) | 9.4(18.9) | - |

*mg/l
Note: TSS: NSM

records by EPA. As discussed for NSSC - sodium base, removal of color by reverse osmosis is equally applicable to NSSC - ammonia base mills.

As mentioned previously, ammonia base NSSC mill effluents contain high concentrations of ammonia for which removal technologies have not yet been demonstrated for the pulp and paper industry. A discussion of potential ammonia removal technologies follows.

## Ammonia Nitrogen Removal

A selective ion exchange system for the removal of ammonia nitrogen has been developed (78) (101) 102) but has not been applied to ammonia base NSSC mills. The process uses a natural zeolite, clinoptilolite which is selective for ammonium ions. Regeneration of the clinoptilolite can be accomplished with a lime slurry which yields an alkaline aqueous ammonious solution. The spent regenerate can then be processed through an air stripping tower to remove the ammonia, with recycle of the regenerate (78) (101) (102). Work showed that the ammonia can be destroyed by electrolysis of the regenerant, which results in the production of chlorine that reacts with the ammonia to produce nitrogen gas (102). A preliminary design report was prepared for the design of a 28.39 million liter per day (97.5 mgd) ammonia ion exchange system to serve the South Tahoe Water Reclamation Plant (78) (102).

In the work undertaken by Battelle-Northwest and the South Tahoe Public Utility District (102), ammonia removal of 93 to 97 percent was reported with a clarified and carbon treated secondary effluent and clarified raw sewage with a 378,500 liters per day (100,000 gpd) mobile pilot plant. Ninety-four percent ammonia removal was obtained with a single 29.26 meter (96 foot) deep bed at 150-bed volumes of Tahoe tertiary effluent, while with a two-column semi-countercurrent operation with 1.43 meter (4.7 foot) deep beds operating at an average of 250-bed volumes, 97 percent ammonia removal was obtained. Ammonia removal averaged 93 percent at an average of 232-bed volumes with clarified raw sewage treated by the two-column, semi-countercurrent operation.

In the work undertaken by the University of California, an average ammonia removal of 95.7 percent was obtained in demonstration studies on three municipal wastes having an NH3-N content of about 20 mg/l. It is stated that ammonia removal to less than 0.5 mg/l NH3-N is technically feasible, but only with shorter runs and greater regenerate requirements.

When using selective ion exchange for ammonia removal, the processing of waste waters with high Mg+2 concentrations may require clarification of the regenerate to avoid plugging of the bed with Mg (OH)2 (102). In addition, it has been stated that secondary effluents may require clarification by plain filtration to prevent fouling of the zeolite beds (78).

Ammonia removal by selective ion exchange is probably best suited to areas where prolonged periods of freezing weather are encountered and where very high degrees of ammonia removal must be maintained. Air-stripping and biological nitrification-denitrification may be used in the warmer climates at a lower cost, but at a somewhat lower efficiency.

Nitrification-denitrification refers to the biological treatment process utilized to convert nitrogen compounds (generally ammonia) to nitrates and nitrates to nitrogen gas. The biological nitrification-denitrification process has been extensively investigated and reported (78) (103) (104) (105) (106).

The nitrifying bacteria are very sensitive to poisoning by simple substances, including heavy metals and free ammonia. Before this process can be used with industrial wastes, therefore, careful testing must be conducted under realistic conditions.

The following factors will influence nitrification (87):

1. Dissolved oxygen level should be above 1.0 mg/l.
2. pH of activated sludge system should be in the range of 7.5-8.5.
3. The growth rate of the nitrifiers is temperature related. Nitrification below 5°C is minimum, while optimum temperature is about 32°C.
4. Growth rate of nitrifiers is reduced by chlorates, cyanides, alkaloids, mercaptans, urethanes, guanidines, methylamine, and nitrourea.

The denitrifying bacteria convert the nitrite and nitrate nitrogen resulting from the nitrification reaction to nitrogen gas.

The three basic requirements for denitrification to proceed are the following (107):

1. An organic carbon source which can be utilized by the dentrifying bacteria.
2. An anaerobic environment.
3. A pH of about 6.5.

The ammonia stripping process can be generally summarized as follows:

1. Raising the pH of the water to 10.5-11.5;
2. Formation and reformation of water droplets (can be easily accomplished in a stripping tower);

3. Circulation of large quantities of air.

Items 1 and 2 above are the same requirements applied to conventional cooling towers and explains the adaptability of these towers to the removal of ammonia.

Discussion of two stripping towers that have been designed for treatment of waste waters is given below. The most well known work done with air stripping of ammonia has been done on municipal wastes at Lake Tahoe (75). A countercurrent stripping tower, 7.62 meters (25 feet) high, 1.83 meters (6 feet) wide, and 1.22 meters (4 feet) in depth was used to investigate the various parameters affecting air stripping of ammonia. The results of these are shown in Figures 29, 30, 31. It is apparent from these figures that the design of air stripping towers can be such as to accommodate any desired ammonia removal up to 90-95 percent removal when ambient air temperatures are above 20°C. As reported (87), the efficiency of the tower was substantially reduced below 20°C. Data obtained with operation of the tower during winter conditions at Lake Tahoe indicated that the average lower limit of the process will be in the range of 50-60 percent ammonia removal. In addition, a stripping tower has been used in conjunction with barometric type evaporator condensers for treatment of final and combined condensates in at least one pulp and paper mill. The mill at 771 metric tons (850 short tons) removed about 6 kg/metric ton (12 lbs/ton) and reduced raw water intake by 30,200-37,800 kiloiters/day (8-10mgd).

The limitations of the use of ammonia stripping towers were first realized with the winter operations at Lake Tahoe. These limitations are outlined as follows (106):

1. When the air temperatures are at 9°C, or below, freezing problems can occur which will restrict air flow.

2. Ammonia solubility increases at the lower temperatures, which results in higher treatment costs.

3. A calcium carbonate scale formation results on the tower because the lime treated wastes are saturated with $CaCO_3$. The scale could be flushed from the Lake Tahoe Tower, but at the EPA's Blue Plains Pilot Plant it was hard and adhered to the tower packing.

Based on the current status of ammonia stripping towers, they probably will only be used in warm climates. In addition, the hard scale problems have to be solved.

Figure 29

EFFECT OF TOWER DEPTH ON AMMONIA REMOVAL

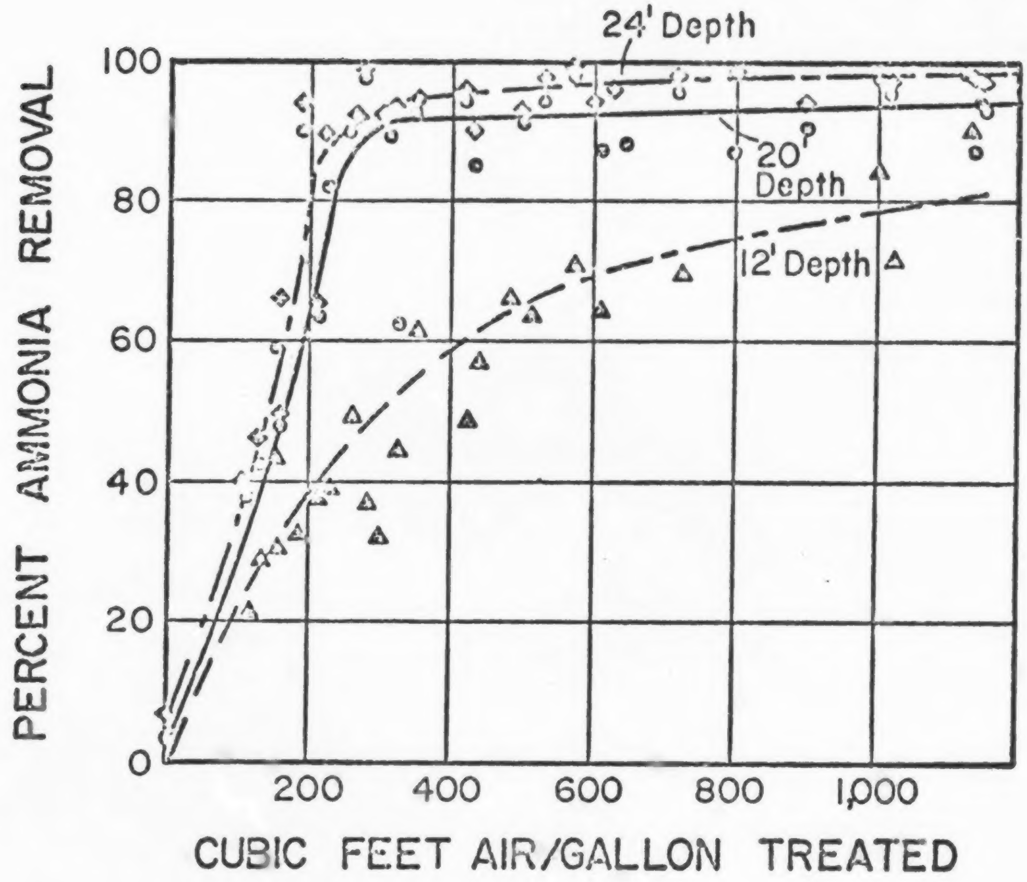


Figure 3C

EFFECTS OF HYDRAULIC LOADING ON AMMONIA REMOVAL AT VARIOUS DEPTHS

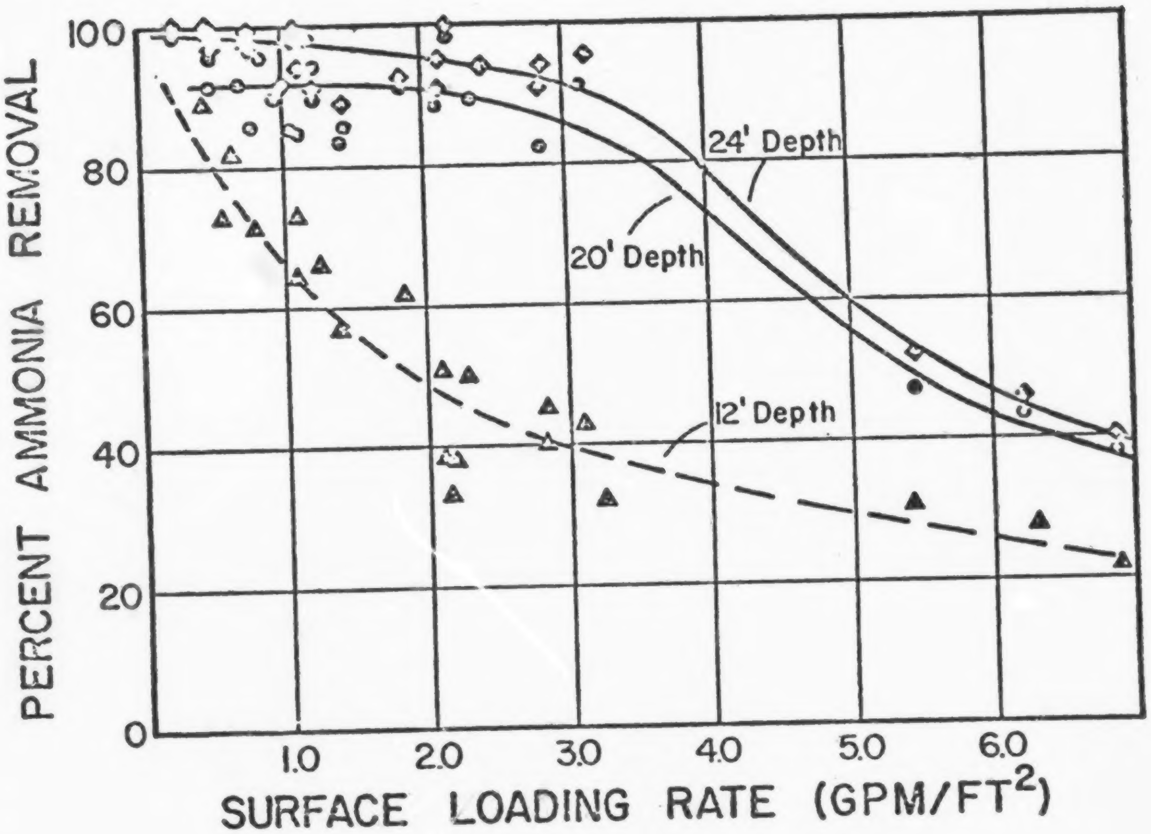
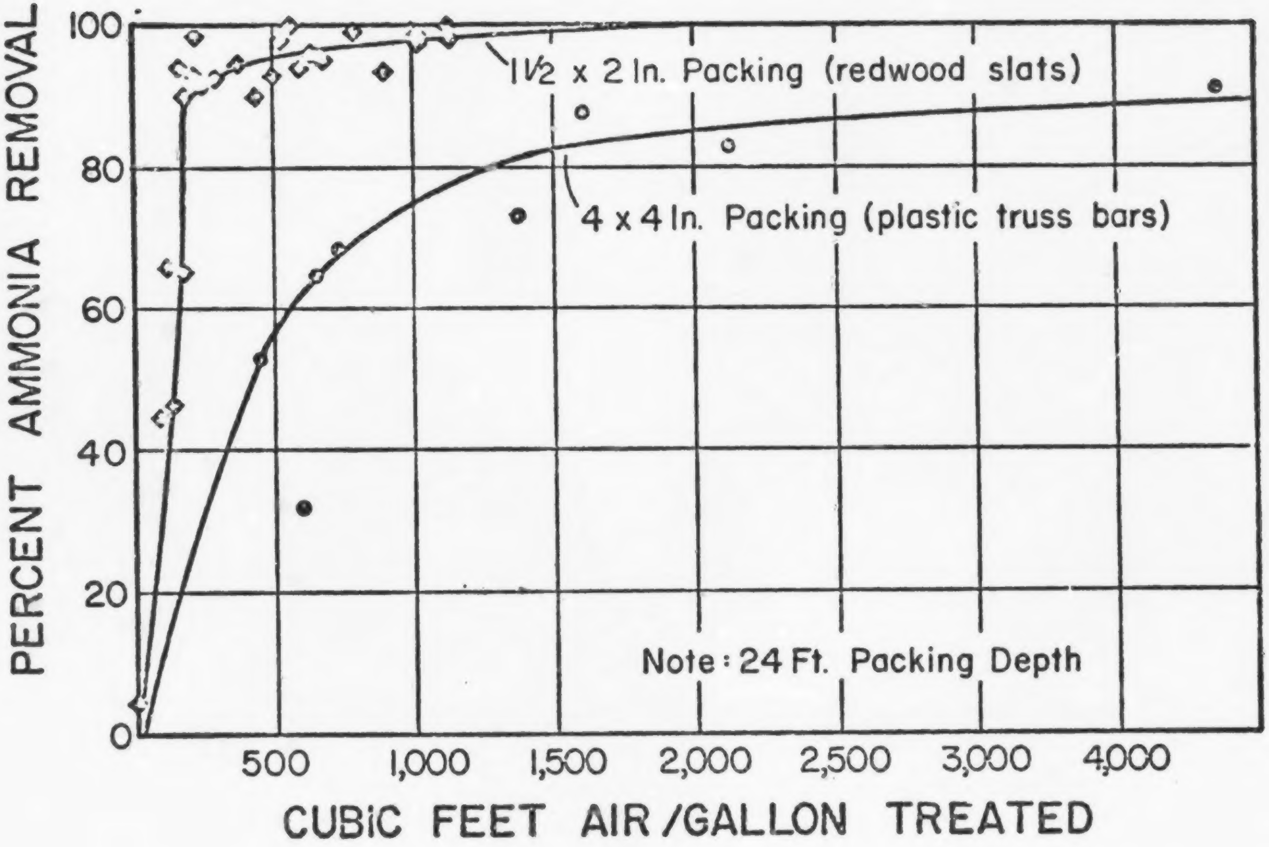


Figure 31

EFFECTS ON PACKING SPACING ON AMMONIA REMOVAL



## KRAFT-NSSC (CROSS RECOVERY)

As shown in Tables 23 and 24, internal and external control technologies applicable to unbleached kraft mills also apply to kraft-NSSC mills with cross recovery and have been discussed previously. Data on four unbleached kraft-NSSC (cross recovery) mills which have secondary treatment and for which secondary treatment effluent data were available are shown in Tables 46 and 47. Specifically, Table 46 shows production, flow, type of treatment, and the TSS analytical measurement technique for each mill. Table 47 shows $BOD_5$ and TSS data for the mills' raw waste and final effluents (Note: AA is the annual average of daily values and MM is the maximum monthly average of daily values). The data generally represent a full year's operation and have been derived from mill records by either EPA or the NCASI.

## TABLE 46

## MILL DATA

## UNBLEACHED KRAFT-NSSC (CROSS RECOVERY)

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment Detention Time (Days) | | Aeration in HP | TSS Method |
|---|---|---|---|---|---|---|
| | | | ASB | SO | ASB | |
| X-1 | 1110(1224) | 57.5(13.8) | 7.5 | 0 | 900 | SM |
| X-2 | 635( 700) | 58.8(14.1) | 7 | 0 | 460 | NSM |
| X-3 | 1824(2011) | 43.4(10.4) | 18 | 4 | 1000 | SM |
| X-4 | 1215(1340) | 74.3(17.8) | 11 | 5 | 1060 | SM |

## TABLE 47

## MILL EFFLUENT DATA

### UNBLEACHED KRAFT-NSSC (CROSS RECOVERY)

(All values in kg/kkg (lbs/ton) except as noted)

| Mill | Raw Waste AA BOD5 | Raw Waste AA TSS | Final Effluent AA BOD5 | Final Effluent MM BOD5 | Final Effluent MM BOD5* | Final Effluent AA TSS | Final Effluent MM TSS | Final Effluent MM TSS* |
|---|---|---|---|---|---|---|---|---|
| X-1 | 24(48) | 28.5(57) | 2.7(5.5) | 3.5(7.1) | 66 | 5(10) | 6.4(12.8) | 118 |
| X-2 | 16.9(33.9)** | 9.7(19.4)** | 4.8(9.7) | 6.0(11.9) | 100 | 3.7(7.5) | 5.7(11.4) | 98 |
| X-3 | 16.3(32.6) | 13.4(24.9) | 3.3(6.7) | 4.7(9.5) | 105 | 2.8(5.6) | 3.4(6.9) | 72 |
| X-4 | - |  | 2.7(5.5) | 3.9(7.8) | 51 | 2.9(5.7) | 5.1(10.3) | 69 |

*mg/1
**Primary Treatment Effluent

## PAPERBOARD FROM WASTE PAPER

### Internal Technologies

A paperboard from waste paper mill utilizes water in its process exclusive of steam generation for the following purposes:

1. Water used for the preparation and transport of fiber through the papermaking process. This is generally recycled water; however, process water that escapes from one stock system to another represents a contribution to the mill effluent to the extent that this intersystem loss occurs. Reduction of the loss of process water from one stock system to another is one type of in-plant control that can be utilized to reduce the raw waste load generated by many mills in this category.

2. Shower water used principally to remove the build-up of fibrous materials on the wet end of the machine which is detrimental to the formation of the product. This water enters the system via shower nozzles and accounts for the largest contribution to the volume of raw waste water generated. The use of recycled process water instead of fresh water for this purpose is essential if major reductions in waste loads generated are to be realized.

3. Water used to permit process equipment to perform its design function. Typical applications are the seal and cooling waters used on pumps, agitators, drives, bearings, vacuum pumps, and process controls. This represents a significant contribution to the volume of waste water generated by the process. In-plant control systems have been developed in many mills that minimize or eliminate this source of waste water generation. The introduction of this source of water to the process system is generally under automatic control and will, in the event of undetected control malfunction, contribute substantially to the waste water volume generated by a mill. Reliable control of these sources of waste water must be included in any in-plant water control system designed to minimize the waste load generated by a mill.

4. Water utilized as non-contact cooling water. The segregation and discharge of this water without treatment has been achieved by many mills and represents in-plant control technology which is essential if near total recycle of process water is a goal.

The water utilization and control technologies described if implemented would make possible very significant reductions in waste loads generated by mills in this category. There are a number of mills that have achieved near total recycle of process water using these or variations of these control technologies. However, for many mills in the industry near total recycle could present a number of production related problems. Those mills that use predominately corrugated waste paper in their furnish could experience excessive dissolved solids buildup in the process water systems which may not be the case for those mills that use predominantly news, mixed, and magazine waste papers. Corrugated waste paper contains adhesives that are relatively high in starch content. This adhesive is dissolved during the stock preparation process and due to its solubility becomes part of the process water system.

The presence of these dissolved solids has no significance for a mill discharging 41,700 liters/kkg (10,000 gal/ton) or more. However, for a mill practicing near complete recycle the attending dissolved solids buildup could create production problems of considerable magnitude. Similar problems could be experienced by those mills that employ on machine coating when near complete process water recycle systems are implemented. Mills that produce food board from a waste paper furnish may experience increasing problems in meeting regulations established by government health authorities due to objectionable odors or other considerations attributable to the implementation of extensive process water recycle concepts.

These are a few of the product grades that have increasing significance as near complete recycle of process water is considered by many mills in this subcategory. Mills that produce a similar grade of product for most of their production time will experience fewer problems if extensive recycle of process water is implemented. However a majority of mills in this subcategory produce these and many other production grades, including food board, all of which can be affected to a greater or lesser extent if a near total recycle of process water system has been implemented.

As shown in Table 23, only a few of the internal control technologies (as discussed for unbleached kraft) for the pulping operation apply. However, all of the control technologies for the stock preparation and paper machine operations apply as were discussed previously for unbleached kraft.

## External Technologies

Since waste paper is fiberized by hydraulic and mechanical means there are no comparable chemical constituents in the mill effluents to the other subcategories resulting from pulping processes. However, the waste treatability is similar to that of the other subcategories, and the external technologies for primary and secondary treatment as discussed previously also apply to paperboard from waste paper mills. Data on nine paperboard from waste paper mills, eight of which have secondary treatment and for which secondary treatment effluent data were available, are shown in Tables 48 and 49. Specifically, Table 48 shows production, flow, type of treatment, and the TSS analytical measurement technique for each mill. Table 49 shows $BOD_5$ and TSS data for the mills' raw waste and final effluents (Note: AA is the annual average of daily values and MM is the maximum monthly average of daily values). The data generally represent a full year's operation and have been derived from mill records by either EPA or the NCASI.

## TABLE 48

## MILL DATA

## PAPERBOARD FROM WASTE PAPER

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment | Aeration in HP | TSS Method |
|---|---|---|---|---|---|
| P-15 | 145 (160) | 68.4 (16.4) | C-ASB | 100 | NSM |
| P-16 | 272 (300) | 12.1 ( 2.9) | C-ASB-C | 300 | SM |
| P-17 | 440 (485) | 19.6 ( 4.7) | ASB-SO | - | SM |
| P-18 | 245 (270) | 38.8 ( 9.3) | C-AS-C | 120 | SM |
| P-19 | 56 (62) | 5.0 ( 1.2) | C-AS-C | - | SM |
| P-20 | 91 (100) | 47.5 (11.4) | C-ASB-HP | 40 | SM |
| P-21 | 145 (160) | 9.5 ( 2.3) | C-ASB | 120 | SM |
| P-22 | 91 (100) | 38.8 ( 9.3) | ASB-DAF | 60 | SM |
| P-23 | 73 (80) | 139.3 (33.4) | DAF | | SM |

# TABLE 49

## MILL EFFLUENT DATA

## PAPERBOARD FROM WASTE PAPER

(All values kg/kkg (lb/ton) except as noted)

| | Raw Waste | | Final Effluent | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mill | AA BOD5 | AA TSS | AA BOD5 | MM BOD5 | MM BOD5* | AA TSS | MM TSS | MM TSS* |
| P-15 | 16.2(32.5) | 72.5(145) | 1.6(3.3) | 2.4(4.9) | 52 | 6.3(12.7) | 8.7(17.4) | 223 |
| P-16 | 10(20) | 9(18) | 0.25(0.5) | 0.7(1.4) | 58 | 1.3(2.6) | 3.6(7.3) | 301 |
| P-17 | 6(12) | - | 0.55(1.1) | 1.6(3.2) | 82 | 0.8(1.6) | 2.0(4.0) | 103 |
| P-18 | 5.5(11)** | 35(70)** | 0.15(0.3) | 0.35(0.7) | 09 | 0.9(1.9) | 1.5(3.1) | 40 |
| P-19 | 4(8) | 4.7(9.5) | 0.1(0.2) | 0.15(0.3) | 17 | 1.0(2.0) | 2.1(4.2) | 383 |
| P-20 | 7.5(15) | 6.5(13) | 1.1(2.2) | 1.9(3.8) | 42 | 1.4(2.8) | 2.7(5.4) | 61 |
| P-21 | 9.5(19) | 2.8(5.6) | 0.3(0.6) | 0.7(1.4) | 74 | 0.55(1.1) | 1.7(3.5) | 186 |
| P-22 | 9(18) | 7.5(15) | 1.0(2.0) | 1.2(2.4) | 31 | 1.8(3.6) | 2.9(5.9) | 75 |
| P-23 | 12.5(25) | 81(162) | 4.0(8.0) | 7.1(14.3) | 21 | 4.5(9.0) | 9.4(18.9) | 28 |

*mg/1
** Primary Treatment Effluent

In the case of many paperboard from waste paper mills which discharge into public sewerage systems, effluent treatment sludges are handled with those contributed by sanitary sewage. Methods are set forth in FWPCA Manual of Practice No. 20 (107) and their effects on the overall process are described in the literature (108).

Sludges from paperboard from waste paper mills can generally be thickened to a consistency in excess of four percent dry solids by prethickening. If activated sludge from secondary treatment is included this figure can be somewhat lower.

## IRRIGATION AND LAND DISPOSAL OF EFFLUENTS

Total mill effluents of pulp and paper mills, as well as specific ones having particularly undesirable properties, have been disposed of by means of irrigation and land disposal. Examples of specific effluents handled in this manner are cooking liquors, foul condensates, and turpentine decanter water.

The advantage of land disposal, when properly practiced, is that a very high degree of purification is obtained on passage through the soil so that the water finally reaching either the adjacent stream or ground water is practically devoid of suspended matter, BOD5, and color. The disadvantages are 1) the relatively small volume that can be disposed of per acre per day - 37,850 to 113,550 liters (10,000 to 30,000 gallons) under most soil conditions, and 2) freezing problems during the winter months, and (3) the potential for imparting taste, odors, or other undesirable characteristics to groundwaters. In some instances, this process is applied only during the critical months when temperatures are high, stream flowages low, and crops, which increase the allowable application rate appreciably, can be grown.

The use of land for the disposal of pulp and paper mill effluents has been applied in the following forms:

1. Seepage ponds
2. Direct application to fallow soil with a wide range of textures by both spray and ridge-and-furrow distribution
3. Application by similar means to soils whose absorption capacity has been modified by development of suitable cover vegetation
4. Controlled effluent application designed to produce crops by use of suitable irrigation practices.

Since these effluents contain little in the way of the basic fertilizer elements, any value they add to the soil other than their irrigating effect is the increased water-holding capacity and friability induced by the stable organic matter present. The use of land disposal and irrigation for disposing of these wastes has been described in detail (110). An assessment of the effectiveness of irrigation on crop growth and the parameters for application of water, BOD5, cellulose, and sodium for soils of different character and textures are set forth.

### Unbleached Kraft

Although considerable demonstration work has been done on the use of kraft mill effluents for irrigating fodder crops, corn, vegetables, and pine trees, there are at present no linerboard mills making large scale use of this means of disposal. Detailed studies of the effects of kraft mill effluents on the soil and its productivity have been published (111) which indicate the suitability of such effluents for irrigation.

However, after applications and trials made to date, this technique has received only minimal acceptance by these mills on a full scale (12).

The major problem is the large volume of effluent produced due to the high production capacity of the mills now operating and the correspondingly large land areas needed. For example, at an application rate of 8,346 liters/kkg (20,000 gal/ton) of product, 2,025 hectares (5,000 acres) of land would be required for a 970 metric tons per day (1,000 short tons per day) linerboard operation. With large land areas, transporting the effluent incurs both extensive capital and operating costs, exceeding those for the common types of waste treatment. This procedure would also necessitate the mill engaging in a business sideline unless there was a neighboring agricultural operation to contract for the waste water. The possibility of spraying the effluent in woodlands to enhance tree growth has been explored but appears unattractive both from the standpoint of its cost and the value received in terms of increased wood yield.

At the present time only one unbleached kraft mill uses land disposal to any extent. It employs seepage ponds seasonally following secondary treatment of the effluent. The major purpose of this is to prevent direct discharge of the treated effluent to the receiving stream during the summer months.

## NSSC

Land disposal of both spent cooking liquor and wash and machine waters from NSSC mills has been described (112). Such disposal was at one time practiced by a number of mills, although only two continue the practice today. This is primarily due to the increasing popularity of cooking liquor disposal by pyroprocesses and treating the remaining waste streams by the treatment methods common to the industry. Thus, only the two most successful of the land disposal systems remain in operation, one of which uses land disposal for spent cooking liquor, and the other employs seepage drains for the entire effluent.

## Paperboard from Waste Paper

There has been no use of irrigation for the disposal of paperboard from waste paper mill effluents. Two mills, both located on small streams, have, however, irrigated fields growing fodder crops during the summer months with treated effluent. This procedure proved very effective for one mill because of its small size and correspondingly small land area requirements.

# SECTION VIII

## COSTS, ENERGY, NON-WATER QUALITY ASPECTS AND IMPLEMENTATION REQUIREMENTS

### RATIONALE FOR DEVELOPMENT OF COSTS

This section of the report summarizes the costs of internal and external effluent treatment associated with technology levels of BPCTCA, BATEA, and New Source Standards of Performance. The cost functions used are for conventional treatment methods based on industry experience with full scale installations and equipment suppliers' estimates. For more advanced processes, where full scale installations are few or nonexistent, the cost estimates are largely based on experience with pilot installations and on estimates from and discussions with equipment suppliers.

It should be recognized that actual treatment costs vary largely from mill to mill depending upon the design and operation of the production facilities and local conditions. Furthermore, effluent treatment costs reported by the industry vary greatly from one installation to another, depending upon bookkeeping procedures. The estimates of effluent volumes and treatment methods described in this section are intended to be descriptive of the segments of the industry that they cover. However, the industry is extremely heterogeneous in that almost every installation has some uniqueness which could be of importance in assessing effluent treatment problems and their associated costs.

For each technology level, the cost of effluent treatment has been summarized for five case studies with regard to type and size of mill. The case situations studied are as follows:

| Type of Mill | Production Capacity kkg/day (tons/day) |
|---|---|
| Unbleached kraft (linerboard) | 907 (1000) |
| NSSC - Sodium base | 227 (250) * |
| NSSC - Ammonia base | 227 (250) * |
| Kraft - NSSC (Cross Recovery) | 907 (1000) |
| Paperboard from Waste Paper | 91 (100) |

* includes use of 50 tons/day waste paper

### Development of Effluent Treatment Costs

Costs of effluent treatment are presented as investment and annual costs. The annual costs are further broken down into capital costs and depreciation. Investment costs are defined as the capital expenditures required to bring the treatment or control technology into operation. These include the traditional expenditures such as design, purchase of land and all mechanical and electrical equipment, instrumentation, site preparation, plant sewers, all construction work, installation and testing, etc.

The capital costs are the financial charges on the capital expenditures for pollution control.

The depreciation is the accounting charges which reflect the deterioration of a capital asset over its useful life. Straight line depreciation has been used in all case study cost calculations.

Operation and maintenance costs are those costs required to operate and maintain the pollution abatement equipment. They include labor, parts, chemicals, energy, insurance, taxes, solid waste disposal, quality control, monitoring and administration, etc. Productivity increases or by-product revenues as a result of improved effluent control are subtracted so that the operation and maintenance costs reported are the net costs.

All costs in this report are expressed in terms of August 1971 prices. This is comparable to the following cost indexes:

| Indexes | Index @ August 1971 |
|---|---|
| EPA Treatment Plant Construction Cost Index (1957-59 = 100) | 164.5 |
| EPA Sewer Line Construction Cost Index (1957-59 = 100) | 166.8 |
| Engineering News Record (ENR) Construction Cost Index (1913 = 100) | 1614 |
| ENR Labor Cost Index (1949 = 100) | 420 |

Effluent treatment or control technology is grouped into internal and external measures. The internal and external treatment technologies which were used to develop treatment costs are shown below. It should be noted that the treatment systems that are shown below may be different than the identified treatment systems in Sections IX, X, and XI. The reason for these differences is that costs were developed for the most expensive case (within practical limits) in order to determine the impact upon the industry.

Available methods for reduction of pollutant discharges by internal measures include effective pulp washing, chemicals and fiber recovery, treatment and reuse of selected waste streams and collection of spills and prevention of "accidental" discharges. Internal measures are essentially reduction of pollutant discharges at their origin and result in recovery of chemicals, by-products, and in conservation of heat and water.

As discussed in Appendix III, the cost of BPCTCA, BATEA, and NSPS for a model mill within each subcategory were developed using the internal and external control technologies in Tables 50 and 51, respectively. It should be noted that the resulting costs include all of the internal technologies whereas, it is not expected that all of the internal technologies need to be installed for a particular mill to meet the limitations. Thus, the resultant costs are for the most expensive situation in order to determine the maximum economic impact.

The costs of the effluent treatment and resulting pollutant reductions are shown in Tables 52, 53, 54, 55, and 56 for unbleached kraft, NSSC-sodium base, NSSC-ammonia base, unbleached kraft-NSSC (cross recovery), and paperboard from waste paper subcategories, respectively.

The treatment unit operations are grouped into pre-, primary, secondary, and tertiary treatment and sludge dewatering and disposal.

Pretreatment includes those processes which are used as required to prepare the effluent for the subsequent treatment steps.

Primary treatment is designed to remove suspended solids and is usually the first major external treatment step.

The primary purpose of secondary treatment is to remove soluble $BOD_5$.

The tertiary treatment steps are designed to remove suspended solids and $BOD_5$ to degrees which are not obtainable through primary and secondary treatment processes, or to remove substances which are refractory to the primary and secondary treatment steps.

## Table 50

## Internal Control Technologies Used in the Development of Costs

### Unbleached Kraft

**BPCTCA**

- addition of spill collection provisions for chemicals and fibers
- installation of low volume, high pressure self cleaning showers on all paper machines
- filtering and reuse of press waters
- pressure screening (hot-stock)
- segregation and reuse of white waters
- collection and reuse of vacuum pump seal waters
- installation of savealls
- gland water reduction

**BATEA**

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

**NSPS**

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

Table 50 (Cont'd)

**NSSC-Sodium**

BPCTCA

- addition of liquor recovery system
- installation of low volume, high pressure self cleaning showers on paper machines
- filtering and reuse of press water
- segregation and reuse of white waters
- collection and reuse of vacuum pump seal waters
- installation of saveall s
- gland water reduction

BATEA

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

NSPS

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

## Table 50 (Cont'd)

NSSC-Ammonia

**BPCTCA**

- segregation and reuse of white waters
- collection and reuse of vacuum pump seal waters
- installation of savealls
- gland water reduction

**BATEA**

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

**NSPS**

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

Table 50 (Cont'd)

Unbleached Kraft-NSSC (Cross Recovery

BPCTCA

- addition of spill collection provisions for chemicals and fibers
- installation of low volume, high pressure self cleaning showers on all paper machines
- filtering and reuse of press waters
- pressure screening (hot-stock)
- collection and reuse of vacuum pump seal waters
- installation of savealls
- gland water reduction

BATEA

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

NSPS

- expanded process water reuse
- separation of cooling water and recovery of heat
- reuse of fresh water filter backwash
- control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately
- reduction of pulp wash and extraction water

Table 50 (Cont'd)

Paperboard from Waste Paper

BPCTCA

- land disposal of junk materials
- installation of low volume, high pressure self cleaning showers on paper machines
- filtering and reuse of press water
- segregation and reuse of white waters
- collection and reuse of vacuum pump seal waters
- installation of savealls
- gland water reduction

BATEA

- land disposal of junk materials
- installation of low volume, high pressure self cleaning showers on paper machines
- filtering and reuse of press water
- segregation and reuse of white waters
- collection and reuse of vacuum pump seal waters
- installation of savealls
- gland water reduction

NSPS

- land disposal of junk materials
- installation of low volume, high pressure self cleaning showers on paper machines
- filtering and reuse of press water
- segregation and reuse of white waters
- collection and reuse of vacuum pump seal waters
- installation of savealls
- gland water reduction

Table 51

## External Control Technologies Used in the Development of Costs

### BPCTCA

Screening, primary, and secondary treatment are provided to total mill effluents for all subcategories, where the screening is by bar screens and primary sedimentation in mechanical clarifiers.

Secondary treatment is provided by nutrient addition and one or two stage biological treatment. An emergency spill basin is installed prior to the secondary treatment step.

All mill effluents receive foam control treatment, monitoring and automatic sampling prior to entering the receiving waters through diffusers.

The sludge is dewatered by vacuum filter and sludge press and sanitary landfilled for kraft and kraft-NSSC mills, while the sludge is dewatered by vacuum filters and sanitary landfilled for NSSC mills and for paperboard from waste paper mills (or reused back into the process).

The screenings are burned in bark burners in case of kraft mills, kraft-NSSC mills, and the NSSC mills. The screenings are sanitary landfilled in case of paperboard from waste paper mills.

### BATEA

All mill effluents are screened by bar screens, and are subjected to primary solids separation in mechanical clarifiers and secondary treatment by nutrient addition and two stage biological treatment. All mill effluents have mixed-media filtration with, if necessary, chemical addition and coagulation. Unbleached kraft and kraft-NSSC (cross recovery) mills have color removal by lime treatment. NSSC-sodium base and NSSC-ammonia base mills have color removal by reverse osmosis.

All mill effluents receive foam control treatment, monitoring and automatic sampling prior to entering the receiving waters through diffusers.

Screenings from the kraft mill and the kraft - NSSC mill effluents are burned in sludge incinerators, and screenings from the NSSC - Sodium and NSSC - Ammonia base mills are burned in existing bark boilers.

Table 51 (Cont'd)

Primary sludges and waste activated sludge are thickened in gravity sludge thickeners, and dewatered mechanically by vacuum filters and presses prior to ultimate disposal.

Ultimate sludge disposal for kraft mills and kraft-NSSC mills is by incineration, and for other subcategories by sanitary landfilling.

NSPS

All mill effluents are screened, receive primary solids separation in mechanical clarifiers, and secondary treatment by nutrient addition, and two stage biological treatment.

Unbleached kraft and kraft - NSSC (cross recovery) mills have color removal by lime treatment. All effluents receive foam control, monitoring and automatic sampling prior to entering the receiving water through diffusers.

Screenings from the kraft mill, the kraft-NSSC mill, the NSSC - Sodium and NSSC - Ammonia mills are burned in existing bark burners. The screenings from paperboard from waste paper mills are disposed of by sanitary landfilling.

Primary sludge and wasted activated sludge are thickened in gravity thickeners prior to mechanical dewatering by vacuum filters and presses.

Sludges from unbleached kraft mills and Kraft-NSSC mills are incinerated, while all other sludges are disposed of by sanitary landfilling.

Table 52

Effluent Treatment Cost and Effluent Quality for 907 mtpd (1000 tpd) Unbleached Kraft (linerboard Mill)

| | None | | | Pre | | | BPCTCA | | | BATEA | | | NSPS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | E | T | I | E | T | I | E | T | I | E | T | I | E | T |
| a. | 0. | 0. | 0. | 2160 | 1820 | 3980 | 5397 | 4873 | 10270 | 6197 | 8536 | 14733 | NA | 10652 | 10327 |
| b. | | | | 394 | 480 | 874 | 1542 | 1133 | 2675 | 1739 | 2437 | 4176 | NA | 2892 | 2751 |
| c. | 0. | 0. | 0. | 324 | 254 | 578 | 810 | 630 | 1440 | 1079 | 1277 | 2356 | NA | 1588 | 1570 |
| d. | 0. | 0. | 0. | 70 | 226 | 296 | 732 | 503 | 1235 | 660 | 1160 | 1820 | NA | 1304 | 1181 |

kg/kkg (Pounds Per Ton)

| | None | Pre | BPCTCA | BATEA | NSPS |
|---|---|---|---|---|---|
| TSS | 35 (70) | 3 (6) | 6.0 (12.0) | 1.85 (3.7) | 3.75 (7.5) |
| BOD5 | 25 (50) | 12 (24) | 2.8 ( 5.6) | 1.35 (2.7) | 1.55 (3.1) |
| Color | - | - | - | 10 (20) | 10 (20) |

kiloliters/kkg (1000 gal/ton)

| None | Pre | BPCTCA | BATEA | NSPS |
|---|---|---|---|---|
| 104 (25) | 50 (12) | 46 (11) | 37.5 (9) | 37.5 (9) |

**Data are in $1000's unless otherwise indicated.**

I = Costs for Internal controls
E = Costs for External controls
T = Sum of costs I and E

a = Investment cost
b = Total annual cost (sum of c and d)
c = Interest cost plus Depreciation cost at 15% per year.
d = Operating and Maintenance cost (including energy and power) per year.

### Table 53

### Effluent Treatment Cost and Quality for 227 mtpd (250 tpd) NSSC - NA Mill

| | None | | | Pre | | | BPCTCA | | | BATEA | | | NSPS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | E | T | I | E | T | I | E | T | I | E | T | I | E | T |
| a | 0. | 0. | 0. | 1785 | 602 | 2387 | 2350 | 1138 | 3488 | 2670 | 2038 | 4708 | NA | 1592 | 1457 |
| b | 0. | 0. | 0. | 744 | 171 | 915 | 869 | 325 | 1194 | 964 | 409 | 1372 | NA | 413 | 356 |
| c | 0. | 0. | 0. | 268 | 81 | 349 | 352 | 145 | 497 | 401 | 306 | 706 | NA | 239 | 219 |
| d | 0. | 0. | 0. | 476 | 90 | 566 | 517 | 180 | 697 | 563 | 103 | 666 | NA | 174 | 137 |

**kg/kkg (lbs/ton)**

| | None | Pre | BPCTCA | BATEA | NSPS |
|---|---|---|---|---|---|
| TSS | 37.5 (75) | 20 (40) | 5.5 (11) | 2.5 (5.0) | 3.85 (7.7) |
| BOD5 | 175 (350) | 45 (90) | 4.35 (8.7) | 2.25(4.5) | 2.6 (5.2) |
| Color | - | - | - | 75% Removal | - |

**kiloliters/kkg (1000 gal/ton)**

| None | Pre | BPCTCA | BATEA | NSPS |
|---|---|---|---|---|
| 62.5 (15) | 50 (12) | 41.7 (10) | 20.8(5) | 20.8(5) |

Table 54

## Effluent Treatment Cost and Quality for 227 mtpd (250 tpd) NSSC NH3 Mill

| | None | | | Pre | | | BPCTCA | | | BATEA | | | NSPS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | E | T | I | E | T | I | E | T | I | E | T | I | E | T |
| a | - | - | - | - | - | - | 0 | 1406 | 1406 | 221 | 1975 | 2196 | NA | 1954 | 1792 |
| b | - | - | - | - | - | - | 0 | 375 | 375 | 95 | 561 | 656 | NA | 528 | 430 |
| c | - | - | - | - | - | - | 0 | 184 | 184 | 49 | 280 | 329 | NA | 284 | 260 |
| d | - | - | - | - | - | - | 0 | 191 | 191 | 46 | 281 | 327 | NA | 244 | 171 |
| kg/kkg (lbs/ton) | | | | | | | | | | | | | | | |
| TSS | | | - | | - | | 5 | (10) | | 2.6 | (5.2) | | 3.75 | (7.5) | |
| BOD5 | | | - | | - | | 4 | (8) | | 3.2 | (6.4) | | 3.75 | (7.5) | |
| Color | | | - | | - | | - | | | 75% removal | | | - | | |
| kiloliters/kkg (1000 gal/ton) | | | | | | | | | | | | | | | |
| | | | - | | - | | 33 | (8) | | 25 | (6) | | 25 | (6) | |

Table 55

## Effluent Treatment Cost and Effluent Quality for 907 mtpd (1000 tpd) Kraft - NSSC Mill

| | None | | | Pre | | | BPCTCA | | | BATEA | | | NSPS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | E | T | I | E | T | I | E | T | I | E | T | I | E | T |
| a | 0. | 0. | 0. | 2501 | 1460 | 3961 | 5229 | 3668 | 8897 | 6269 | 8232 | 14501 | NA | 9864 | 9580 |
| b | 0. | 0. | 0. | 440 | 400 | 880 | 1888 | 934 | 2822 | 2067 | 2401 | 4468 | NA | 2848 | 2705 |
| c | 0. | 0. | 0. | 360 | 190 | 550 | 1193 | 504 | 1697 | 1432 | 1263 | 2695 | NA | 1514 | 1471 |
| d | 0. | 0. | 0. | 80 | 210 | 290 | 695 | 430 | 1125 | 635 | 1138 | 1773 | NA | 1334 | 1234 |

| | None | Pre | BPCTCA | BATEA | NSPS |
|---|---|---|---|---|---|
| **kg/kkg (lbs/ton)** | | | | | |
| TSS | 35 (70) | 3.5 (7) | 6.25 (12.5) | 2.1 (4.2) | 4.0 (8.0) |
| BOD5 | 30 (60) | 24.5 (49) | 4.0 ( 8.0) | 1.6 (3.2) | 2.9 (3.8) |
| Color | - | - | - | 12.5 (25) | 12.5 (25) |
| **kiloliters/kkg (1000 gal/ton)** | | | | | |
| | 92 (22) | 75 (18) | 54 (13) | 33 (8) | 33 (8) |

Table 56

## Effluent Treatment Cost and Quality for 91 mtpd (100 tpd) Paperboard from Waste Paper

| | None | | | Pre | | | BPCTCA | | | BATEA | | | NSPS | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | I | E | T | I | E | T | I | E | T | I | E | T | I | E | T |
| a | 0. | 0. | 0. | 105 | 314 | 419 | 422 | 561 | 983 | 422 | 801 | 1223 | NA | 415 | 314 |
| b | 0. | 0. | 0. | 29 | 76 | 105 | 104 | 155 | 259 | 104 | 190 | 294 | NA | 103 | 76 |
| c | 0. | 0. | 0. | 15 | 42 | 57 | 63 | 74 | 137 | 63 | 115 | 173 | NA | 57 | 42 |
| d | 0. | 0. | 0. | 14 | 34 | 48 | 41 | 81 | 122 | 41 | 75 | 116 | NA | 46 | 34 |
| **kg/kkg (lbs/ton)** | | | | | | | | | | | | | | | |
| TSS | | | 40 (80) | | | 4 (8) | | | 2.5 (5.0) | | | 0.8 (1.6) | | | 2.0 (4.0) |
| BOD5 | | | 35 (70) | | | 15 (30) | | | 1.5 (3.0) | | | 0.65 (13) | | | 0.75 (1.5) |
| **kiloliters/kkg (1000 gal/ton)** | | | | | | | | | | | | | | | |
| | | | 50 (12) | | | 25 (6) | | | 12.5 (3) | | | 8.3 (2) | | | 8.3 (2) |

Note: In going from *) to **) practical considerations dictate that the internal investment be made at BPCTCA. Therefore although a decrease in internal water use is expected between BPCTCA and BATEA, the total required investment is given in BPCTCA.

## ENERGY REQUIREMENTS

As previously stated, the costs shown above do not include energy costs. Specific energy and power prices have been developed based on the following:

External treatment

power cost = 1.1¢/KWH
fuel price = $0.24/million Kg Cal ($0.95/million BTU)

Internal treatment

steam = $1.86/metric ton ($2.05/short ton)
power = 0.6¢/KWH

The lower power unit price used for internal treatment takes into consideration the lower cost of power generated by the mill, while power from external sources is assumed for external treatment.

Power costs are reported on Table 57 as annual expenditures.

Estimated energy requirements for application of BPCTCA, BATEA, and NSPS are shown in Table 58.

## TABLE 57

| Type of Mill | POWER COSTS, $1000<br>Technology Level | | |
|---|---|---|---|
| | BPCTCA | BATEA | NSPS (2) |
| Unbleached Kraft<br>907 kkg/day (1000 tons/day) | 248 | 499 | 609 |
| NSSC-Sodium Base<br>227 kkg/day (250 tons/day) | 121 | 147 | 65 |
| NSSC-Ammonia Base<br>227 kkg/day (250 tons/day) | 73 | 88 (1) | 91 (1) |
| Kraft-NSSC<br>907 kkg/day (1000 tons/day) | 232 | 503 | 509 |
| Paperboard from Waste paper<br>91 kkg/day (100 tons/day) | 44 | 42 | 27 |

---

(1) Costs for removal of nitrogen are not included because of lack of sufficient data.

(2) Costs for NSPS treatment and control technology do not include expenditures necessary for internal mill improvements. Sufficient data were not available to establish this portion of the costs.

## TABLE 58

## ENERGY REQUIREMENTS

| | BPCTCA | | BATEA | | NSPS | |
|---|---|---|---|---|---|---|
| | kwh/kkg | (kwh)/(ton) | kwh/kkg | (kwh)/(ton) | kwh/kkg | (kwh)/(ton) |
| Unbleached Kraft<br>907 kkg/day (1000 tons/day) | 54 | (60) | 106 | (117) | 91 | (100) |
| NSSC-Sodium Base<br>227 kkg/day (250 tons/day) | 108 | (119) | 135 | (149) | 116 | (127) |
| NSSC-Ammonia Base<br>227 kkg/day (250 tons/day) | 106 | (117) | 190 | (210) | 161 | (178) |
| Kraft-NSSC<br>907 kkg/day (1000 tons/day) | 70 | (77) | 122 | (135) | 113 | (125) |
| Paperboard<br>91 kkg/day (100 tons/day) | 120 | (132) | 217 | (239) | 211 | (233) |

## NON-WATER QUALITY ASPECTS OF CONTROL AND TREATMENT TECHNOLOGIES

### Air Pollution Potential

There are several potential air pollution problems associated with the external treatment of effluents from mills in each of the subcategories.

When properly designed and operated, primary and biological treatment do not produce odors associated with anaerobic decomposition. However, biological treatment of unbleached kraft and NSSC waste waters does result in very localized odors, especially when mechanical aeration is employed. The odor is characterized as wood extractives.

There are air pollution problems associated with the treatment of wastes in the ammonia base NSSC subcategory. These take two forms. First is the odor of ammonia arising from the treatment itself. While ammonia is not present in high concentrations, the odors can be objectionable under low-wind conditions close to the treatment site. Secondly, the synergistic combination of gaseous ammonia with other elements in the atmosphere, such as sulfur dioxide, is believed to be responsible for a localized atmospheric haze under certain conditions. Similar combinations may be responsible for observed damage to new growth ends of pine trees.

Odors can arise from improper land disposal of liquid sludges as a result of their anaerobic decomposition. These derive primarily from organic acids and hydrogen sulfide produced on reduction of sulfates dissolved in the water content of the sludges. Dewatering prior to disposal on the land inhibits such decomposition, thus reducing odors. The use of sanitary landfill practices will also mitigate odor problems.

Presently sludge lagooning is largely limited to unbleached kraft mills on large sites. The low level of odor produced is generally confined to company property. The practice of decanting free water from lagoons and returning it to the treatment system has noticeably reduced the odor level in their immediate environs.

Incineration of sludges produced in the effluent treatment processes can, without appropriate control equipment, result in the discharge of particulates to the atmosphere. However, emission control devices are available to meet state regulatory requirements in most instances. Incinerators are either sold with integral emission control appliances or are equipped with them on installation. Gaseous pollutant emissions from such incinerators are negligible.

In-mill controls which effect a reduction in fiber and additive losses, such as save-alls, recycling of process waters, and removal of dregs and grits in the unbleached kraft recovery process, are not producers of air pollution. On the other hand, recovery of cooking chemicals in the kraft process, which, in addition to its principal function of conserving expensive raw materials, also serves to reduce chemical waste load, produces odorous sulfur compounds. When these escape the recovery furnace to the atmosphere, they become the major air pollution problems of the mill. These emissions and measures to control them are described in a report prepared for an EPA predecessor agency entitled "Control of Atmospheric Emissions in the Wood Pulping Industry" (113).

## Noise Potential

There are no official records of public noise problems arising from the operation of effluent treatment works by the subject subcategories of mills. However, based on many years of contractor association with industry operations, it can be stated that public complaints engendered by such noise are very infrequent. This is due in all probability to the remote location of most large treatment works or to their confinement, in some instances, to manufacturing or utility areas. Also, the noise level of most of the devices employed for treatment is generally lower than that of some manufacturing machinery.

The sources of noise are for the most part air compressors or mechanical surface aerators supplying air to treatment processes, vacuum pumps and centrifuges involved in sludge dewatering, and fans serving sludge incinerators. With the exception of surface aerators, these devices are most frequently operated in buildings which serve to muffle their noise.

Small surface aerators are generally found in small mills which are more likely to be located closer to habitation. Units of this size, particularly those not driven through gear boxes, produce little noise. The problem of noise emanating from gear boxes is the subject of an extensive investigation by the Philadelphia Gear Company which manufactures many of these units. It is anticipated that this study will lead to a reduction in noise from these sources. Noise produced by the large aerator units which are usually operated away from built-up areas is neither high-level nor far-carrying.

It can be concluded that noise produced by equipment used for treating pulp and paper mill effluent is not a major public problem at present. Efforts underway to reduce the noise level of mechanical equipment in general, stimulated by industrial health protection programs, will assist in preventing it from becoming one.

## Solid Wastes and Their Disposal

In addition to sludges produced by effluent treatment, the following wastes are or can be produced at mills in the subcategories covered by this survey:

### UNBLEACHED KRAFT MILLS
(and Kraft-NSSC)

- Bark
- Rejects and Screenings
- Grits and Dregs
- Log wash Water
- Ash
- Waste Paper
- Garbage
- Trash

### NSSC MILLS

- Bark
- Rejects and Screenings
- Chemical Ash
- Ash
- Waste Paper
- Garbage
- Trash

### PAPERBOARD FROM WASTE PAPER MILLS

- Trash
- Waste Paper
- Fly Ash
- Garbage

Linerboard mills which bark roundwood on the premises produce sufficient bark to fire a boiler for steam generation so the necessity for its disposal is eliminated. Others receive their wood supply in the form of chips which are a by-product of lumbering operations, and no bark is involved.

Rejects and screenings from linerboard mills are either reprocessed, burned in incinerators or in the bark-fired boilers or disposed of by land fill. The latter procedure represents no problem for most of these mills because of the large mill sites containing considerable usable land. Grits and dregs from the causticizing system of the recovery plant are inorganic solids which are generally water carried to a land disposal site. This is facilitated by their small quantity which amounts to about 22.5 kg/kkg (45 lbs/ton) of pulp produced.

Ash from bark- and coal-fired boilers and screening rejects are as a rule discharged hydraulically to ash ponds. There the solids settle and compact and the clear supernatant water is discharged to the mill effluent system. In some instances, ash and rejects are hauled to a disposal area away from the mill site. Wet handling of these materials avoids their being blown into the atmosphere.

Overflow from log washing operations which contains silt and fine bark particles generally joins the stream carrying ash from the mill.

Waste paper, garbage, and trash attendant to production or accessory operations and activities are either incinerated on the site or hauled away for disposal by contractors engaged in this business.

NSSC corrugating board mills generate most of the kinds of solid wastes created at linerboard mills and handle them in a similar manner. One exception is that most of these mills are relatively small operations which do not produce enough bark to justify a steam-generating bark boiler. The bark is usually disposed of in incinerators designed for this purpose.

At NSSC mills where spent liquor is burned in fluidized bed units, ash consisting of a mixture of sodium carbonate and sodium sulfate is produced. This is usually sold to kraft mills to be used as a make-up chemical replacing salt cake in the recovery system.

At paperboard from waste paper mills, trash, such as rags, wire and other metals, glass, and plastics, is removed in the breaker beater and stock cleaning operations. This material, and grit from the rifflers, is disposed of by land fill on the mill premises or hauled to a suitable location for disposal in this manner.

The remaining solids wastes such as ash, waste paper, etc., are handled as described above.

Particulate emissions from incineration of bark and other solid wastes must be controlled by effective devices such as bag filters or scrubbers.

Research has recently been conducted on solid wastes generated in the pulp and paper industry and their disposal for EPA's Office of Solid Waste Management Programs (EPA Contract No. 68-03-0207).

## By-product Recovery

The unbleached kraft process is the only subject subcategory in which significant quantities of by-products are recovered. The two major saleable by-products of this process are turpentine and tall oil, both in a crude form which is usually refined elsewhere.

Digester relief gases are the source of crude sulfate turpentine. The gases are condensed and the crude oil fractions decanted from the water fraction. The turpentine requires distillation to remove the objectionable odor of the sulfur compounds present. Generally crude turpentine is shipped from the mills for rectification by chemical plants.

Turpentine yields vary with wood specie (114) and cooking variables. A 1969 study (115) reported yields ranging from 6.3-17.9 liters/kkg (1.5-4.3 gal/ton) of pulp; its market value was estimated at 18¢-36¢/kkg (20¢-40¢/short ton); and its recovery was calculated to represent approximately one percent diminution of the pollution load in terms of $BOD_5$. Its removal from the mill effluent is actually of much greater significance since it has a high toxicity level for aquatic life. It is used primarily in paint thinners and in the manufacture of insecticides.

A light fraction of the distilled turpentine contains dimethyl sulfide which can be removed and converted to dimethyl sulfoxide, an excellent industrial solvent (13).

Tall oil components are recovered from kraft black liquor at various points in the chemical recovery system in the form of sodium soap skimmings. These are acidified with sulfuric acid to produce tall oil and the spent acid which consists primarily of sodium sulfate is returned to the black liquor as chemical make-up. Tall oil consists of a mixture of resin and fatty acids, and its derivatives are used to make adhesives, emulsions, paints, disinfectants, and soaps (115).

Tall oil yield per metric ton of kraft peaked in 1968 at about 47.5 kg/kkg (95 lbs/ton) and has declined to about 34 kg/kkg (78 lbs/ton) in 1973. (116). Normal variations occur depending on the fatty content of the wood, skimmer efficiency, and other factors. Efficiency of recovery now averages about 75-80 percent (117).

Fluctuations in price also occur due to market factors and a considerable range may be found in the literature. The most recent price quoted is $72.56 per kkg ($80 per ton), a 25 percent increase over the past five years (116). The economic incentive for increased soap recovery may expand the corollary benefits of recovery which have a direct bearing on raw waste load.

The presence of soap in black liquor accelerates fouling of the evaporators which in turn affects required heat differences. This creates the necessity for more frequent boil-out during which liquor losses inevitably occur. Frequent skimming of the weak liquor storage tanks is needed in addition to evaporator skimming to prevent soap being pulled into the evaporator feed during low liquor inventory. The resultant foaming can create evaporator upset which will require boil-out to restore stability (117).

Mill practices which will permit more complete recovery of turpentine and tall oil are forecast. For example, shorter storage of chips or precooking extraction would prevent the loss of turpentine and tall oil by oxygenation prior to pulping. Solvent extraction of the soap from black liquor could improve recovery efficiencies.

On the other hand there are factors which will inhibit recovery of these by-products. Increased use of continuous digesters will reduce the yield of turpentine thus creating a need for an economic method of turpentine recovery from the black liquor in continuous processes. Mixing pine and hardwood black liquors reduces the recovery of tall oil and separate liquor tanks will be required (117). Use of more hardwood, sawmill wastes, immature wood, and outside chip storage are other adverse factors (116).

Production of other by-products, such as methanol, acetic acid, tars, etc., on a commercial scale is not yet economically feasible. Effluent limitations and standards are expected to stimulate increased research on by-product recovery in the next decade.

## IMPLEMENTATION REQUIREMENTS

### Availability of Equipment

Since 1966, when Federal water pollution control expenditures began, various Federal and private organizations have analyzed the projected levels of water pollution control activity and their economic impact on the construction and equipment industries. As a result, a plethora of studies has been developed which is related to the levels of municipal and industrial water pollution control construction and the respective markets for waste water treatment equipment. Less information is available concerning the actual and anticipated levels of expenditure by any specific industry.

In recent years, the trend in the waste water equipment industry has seen the larger firms acquiring smaller companies in order to broaden their market coverage.

Figure 32 shows graphically past expenditures and projected future outlays for the construction of industrial waste water treatment facilities, as well as total water pollution control expenditures. Obviously, the level of expenditures by industry is related to the Federal compliance schedule. This will increase until industry is in compliance with Federal standards. Once that occurs, the level of spending will return to a level commensurate with the construction of new facilities, replacement of existing facilities, and the construction of advanced waste treatment facilities.

Figure 33 shows past expenditures for and projected future trends in total sales of waste water treatment equipment and the dollar amounts attributable to industrial and municipal sales. This curve closely follows the trend shown in Figure 32.

The data in Figures 32 and 33 related to industrial water pollution expenditures include only those costs external to the industrial activity. Internal process changes made to accomplish water pollution control are not included.

Recent market studies have projected the total available production capacity for water and waste water treatment equipment. Most of them have indicated that the level of sales is currently only 30-40 percent of the total available plant capacity. Several major manufacturers were contacted to verify these figures and indications are that they are still accurate. A partial reason for this overcapacity is that the demand for equipment has been lower than anticipated. Production capacity was increased assuming Federal expenditures in accord with funds authorized by Congress and conformance to compliance schedules.

For the immediate future, increased demands for waste water treatment equipment can be absorbed by the existing overcapacity. Long term requirements will probably necessitate expansion of production capacity

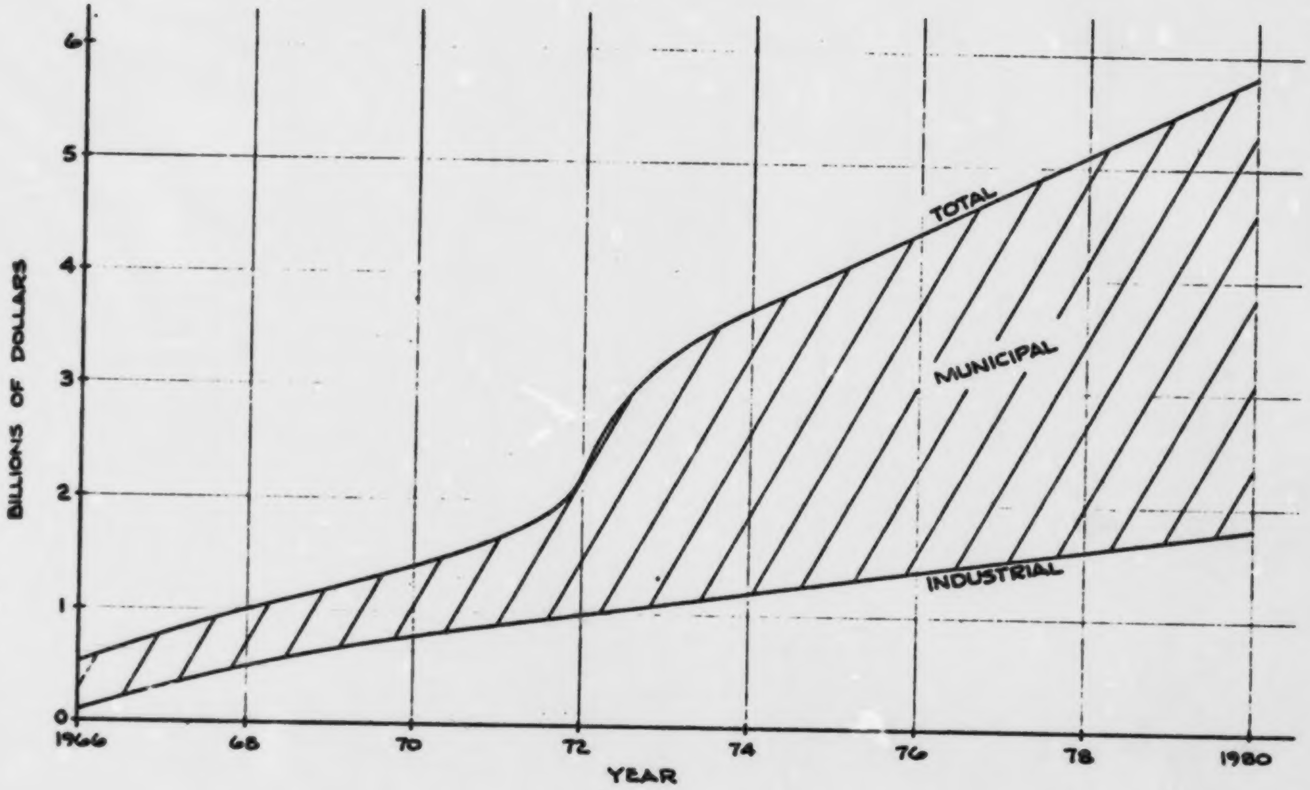


FIGURE 32
TOTAL WATER POLLUTION
CONTROL EXPENDITURES

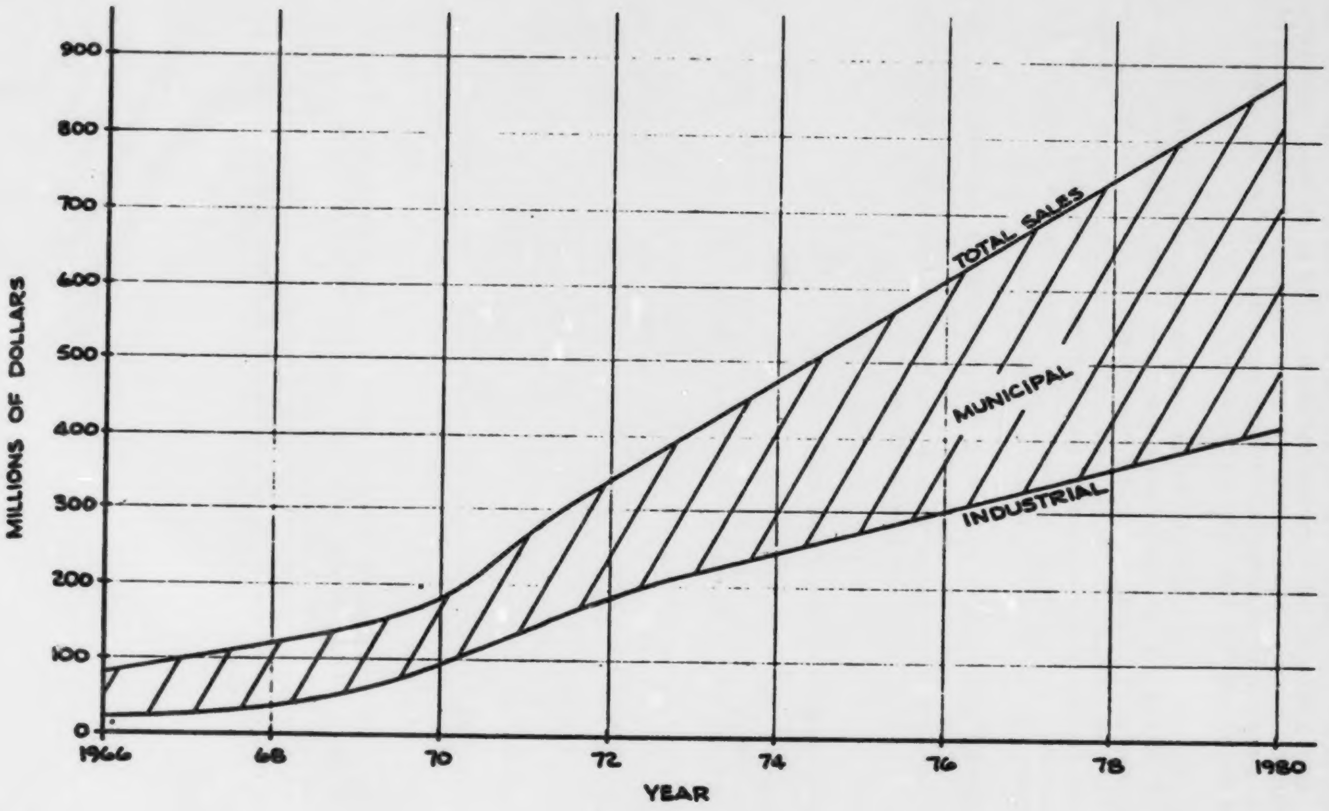


FIGURE 33
WASTEWATER TREATMENT
EQUIPMENT SALES

in various product lines where the demand is expected to increase dramatically -- specifically, advanced treatment systems and waste solids handling equipment.

It should also be noted that the capacity to produce waste water treatment equipment could be expanded significantly through the use of independent metal fabricators as subcontractors. Even at the present time independent fabricators are used by some equipment manufacturers when work loads are heavy and excessive shipping costs make it desirable to use a fabricator close to the delivery site.

There appear to be no substantial geographical limitations to the distribution of waste water treatment equipment to industry. In various areas, certain suppliers may be more successful than others; however, this seems to be related more to the effectiveness of the sales activities than to as geographical limitations. The use of independent metal fabricators as subcontractors to manufacture certain pieces of equipment further reduces geographical limitations.

Equipment delivery schedules may vary substantially depending upon the manufacturer, the current demand, and the specific equipment in question. Obviously, the greater the demand or the more specialized the equipment, the greater the delivery time.

## Availability of Construction Manpower

After consultation with the Associated General Contractors of America and other industry groups, it is concluded that sufficient manpower exists to construct any required treatment facilities.

This conclusion has reportedly been substantiated by EPA in an independent study although there is still some concern about localized problems (118). The Bureau of Labor Statistics has been requested to conduct another study.

## Construction Cost Index

The most detailed study and careful analysis of cost trends in prior years still leave much to be desired in predicting construction costs through the next ten years.

During the years 1955 through 1965 there was a very consistent price rise. The Engineering News Record (ENR) Construction Cost Index in January 1955 was 644. With slight deviations from a straight line, costs rose at a steady rate to an index of 988 in December 1965. This represented an increased cost of 53.4 percent over an 11 year period of approximately five percent per year.

The first six months of 1966 saw an increase of 6.6 percent then leveled off abruptly only to rise sharply again in 1967 at a rate of 6.2 percent, then increasing to 9.4 percent in 1968.

The increase in costs continued to rise at about 10.5 percent per year through 1970. During 1971, construction costs rose at the unprecedented rate of 15.7 percent primarily due to larger increases in labor rates.

With the application of Federal wage and price controls in 1972, the rate of increase dropped to 8.7 percent. The first three months of 1973 saw some escalation of costs due to allowable materials price gains (106). EPA determined the increase in Treatment Plant Construction Cost during this period to be 3.1 percent. This compares with a rise of only 0.9 percent during the previous three months.

The opinion of some officials of the Associated General Contractors is that the rate of cost increase for general construction work, including waste water treatment and industrial construction, should average no more than five to six percent over the next several years. This is, therefore, the basis used for extension of the ENR Index curve at an annual six percent increase for construction costs through the year 1983. This is shown in Figure 34.

## Land Requirements

Land requirements for a number of external treatment systems have been evaluated and are shown in Figure 35 for a range of plant sizes. Incineration or off-site disposal of dewatered sludge has been assumed. Should sludge lagoons be used on site, additional land would be required.

## Time Required to Construct Treatment Facilities

The time required to construct treatment facilities has been determined for a range of plant sizes and for two different project contract possibilities. The treatment sizes evaluated were under 18.9 MLD (5 MGD), 18.9 - 37.8 MLD (5-10 MGD), and over 37.8 MLD (10 MGD). The contract bases evaluated were 1) separate engineering and construction and 2) turnkey performance. The components considered for both approaches included preliminary engineering, final design engineering, bid and construction award, and construction.

It is concluded from reviewing the data shown in Figure 36 that it should be possible in all cases to meet the implementation requirements of the July 1977 deadlines.

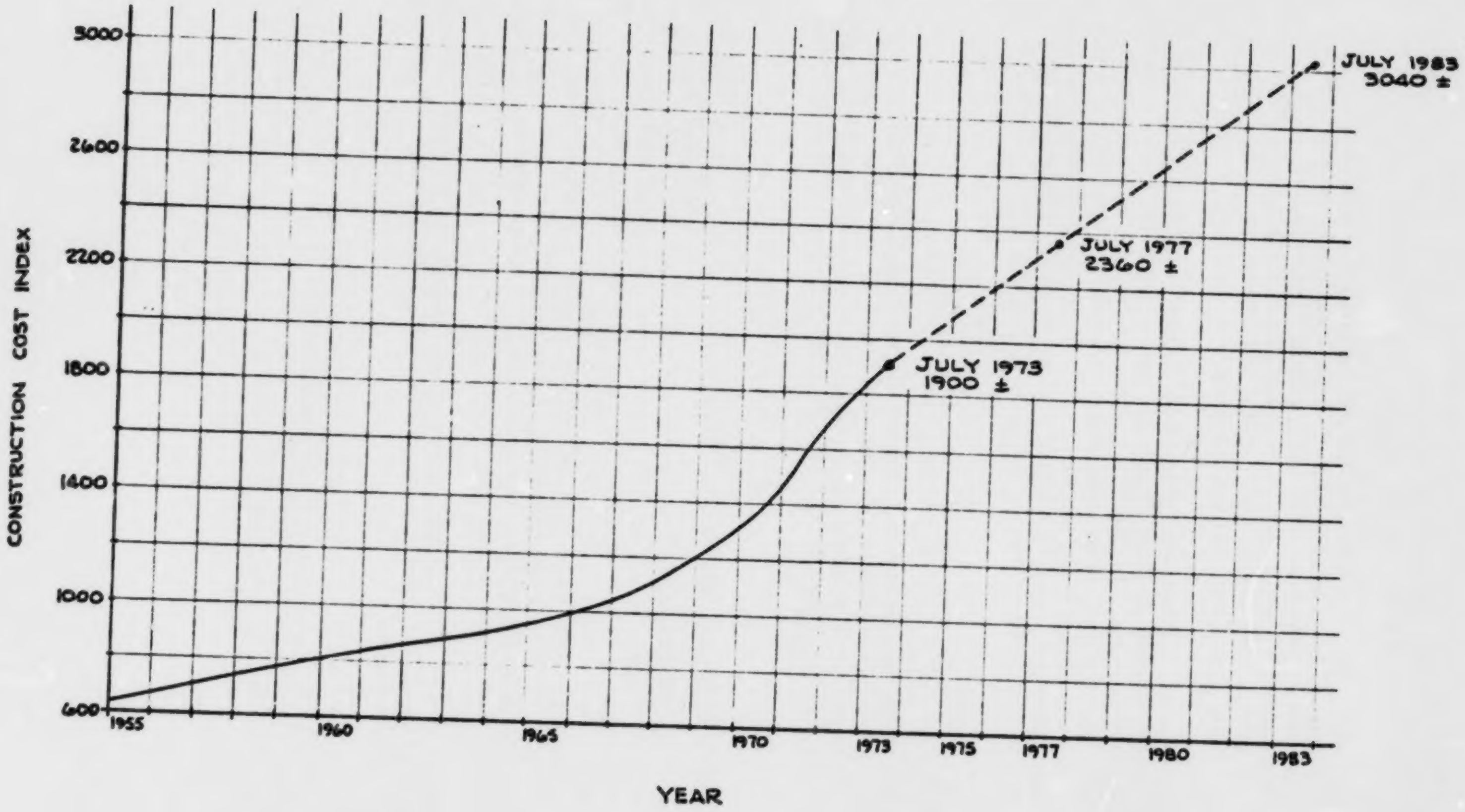


FIGURE 34
ENGINEERING NEWS RECORD
CONSTRUCTION COST INDEX

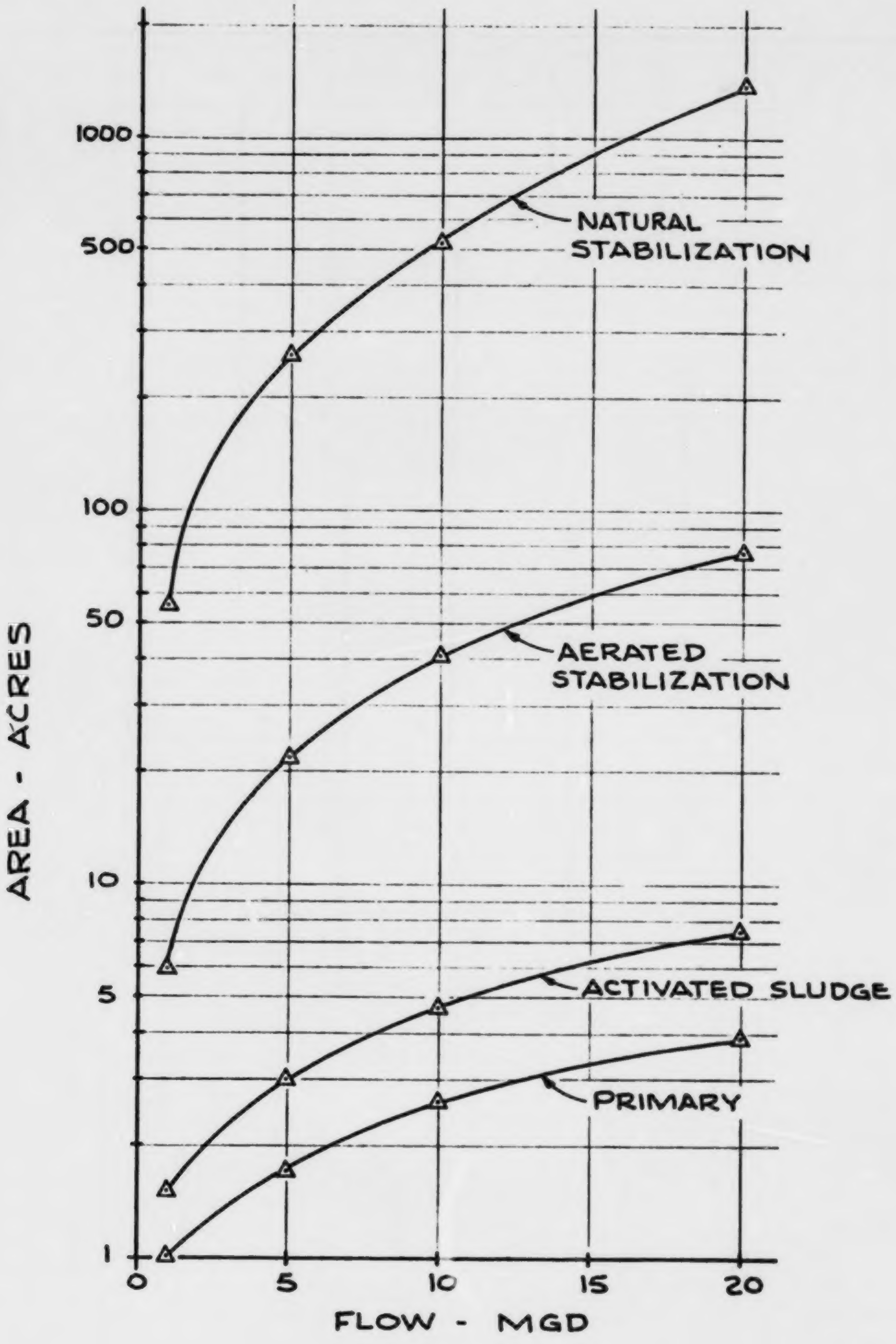


FIGURE 35
LAND REQUIRED FOR
WASTEWATER TREATMENT

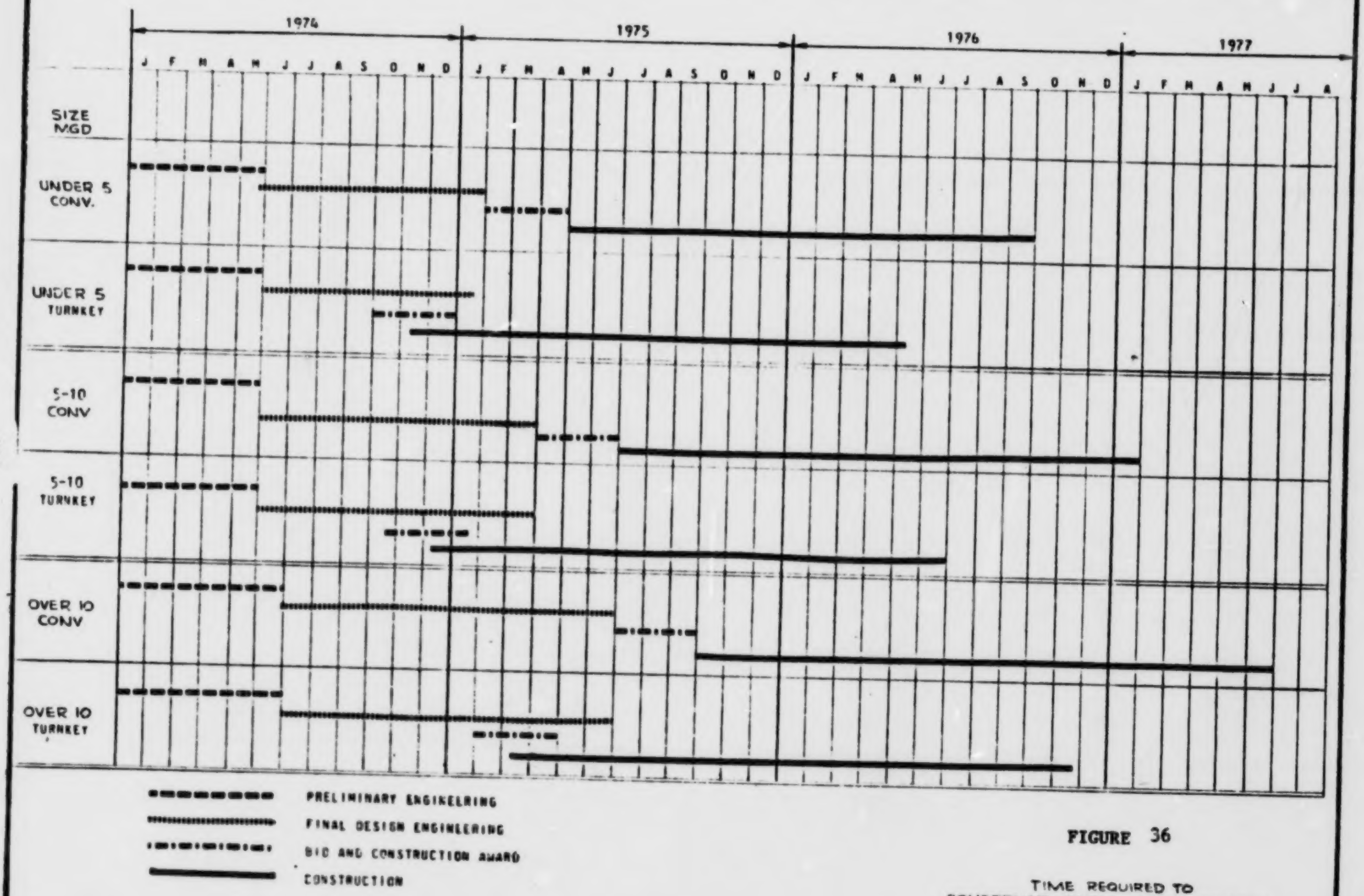


FIGURE 36

TIME REQUIRED TO
CONSTRUCT WASTEWATER FACILITIES
CONVENTIONAL & TURNKEY CONTRACTS

# SECTION IX

# BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

## INTRODUCTION

The effluent limitations which must be achieved by July 1, 1977 are to specify the degree of effluent reduction attainable through the application of the Best Practicable Control Technology Currently Available. Best Practicable Control Technology Currently Available is generally based upon the average of the best existing performance by plants of various sizes, ages, and unit processes within the industrial subcategory.

Consideration was also be given to:

a. the total cost of application of technology in relation to the effluent reduction benefits to be achieved from such application;

b. the size and age of equipment and facilities involved;

c. the process employed;

d. the engineering aspects of the application of various types of control techniques;

e. process changes;

f. non-water quality environmental impact (including energy requirements).

Also, Best Practicable Control Technology Currently Available emphasizes treatment facilities at the end of a manufacturing process but includes the control technologies within the process itself when the latter are considered to be normal practice within a subcategory.

A further consideration is the degree of economic feasibility and engineering reliability which must be established for the technology to be "currently available." As a result of demonstration projects, pilot plants, and general use, there must exist a high degree of confidence in the engineering and economic practicability of the technology at the time of commencement of construction or installation of the control facilities.

## EFFLUENT REDUCTION ATTAINABLE THROUGH THE APPLICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Based upon the information contained in Sections III through VIII and in the Appendices in this report, a determination has been made that the point source discharge limitations for each identified pollutant, as shown in Table 59, can be obtained through the application of the best practicable pollution control technology currently available.

Table 59

BPCTCA Effluent Limitations

Values in kg/kkg (lbs/ton)

| | BOD5 | | TSS | |
|---|---|---|---|---|
| Subcategory | 30 Day | Daily Max | 30 Day | Daily Max |
| Unbleached Kraft | 2.8 (5.6) | 5.6 (11.2) | 6.0 (12.0) | 12.0 (24.0) |
| NSSC-Ammonia | 4.0 (8.0) | 8.0 (16.0) | 5.0 (10.0) | 10.0 (20.0) |
| NSSC-Sodium | 4.35 (8.7) | 8.7 (17.4) | 5.5 (11.0) | 11.0 (22.0) |
| Unbleached Kraft-NSSC | 4.0 (8.0) | 8.0 (16.0) | 6.25 (12.5) | 12.5 (25.0) |
| Paperboard from Waste Paper | 1.5 (3.0) | 3.0 (6.0) | 2.5 (5.0) | 5.0 (10.0) |

pH for all subcategories shall be within the range of 6.0 to 9.0

The maximum average of daily values for any thirty consecutive day period should not exceed the 30 day effluent limitations shown above. The maximum for any one day should not exceed the daily maximum effluent limitations as shown above. The limitations shown above are in kilograms of pollutant per metric ton of production (pounds of pollutant per short ton of production). Production is defined as the annual average level of production off the machine (air dry tons). Effluents should always be within the pH range of 6.0 to 9.0.

The TSS parameter is measued by the technique utilizing glass fiber filter disks as specified in Standard Methods for the Examination of Water and Wastewater (13th Edition) (1).

## IDENTIFICATION OF BEST PRACTICABLE CONTROL TECHNOLOGY CURRENTLY AVAILABLE

Best practicable control technology currently available is the same for all subject subcategories with regard to external treatment of industrial wastes. However, applicable technology in normal use varies between subcategories for internal control measures. The internal controls identified are in common use among the subcategories. Approximately 60-100% of mills within the subcategories studied use some or all of the identified internal controls. The following is a discussion of both these internal and external controls. It should be emphasized that it is not expected that all of the internal controls listed are needed for mills to meet the limitations. Also, the internal controls, as well as the external controls, are identifications (not requirements) of pollution control technologies which can be utilized to meet the BPCTCA limitations. In addition, mills have the option for pollutant reduction by well designed and operated external treatment systems or by a combination of both internal and external controls which may prove to be more cost effective.

### Internal Control

### Unbleached Kraft

a. Hot Stock Screening

As explained in Section VII, this is a process modification in which the pulp is passed through a fibrolizer to fractionate knots and then through a hot stock screen to remove shives. This sequence avoids the need for dilution of the pulp for screening and subsequent decker sewer losses. This should be accomplished without increasing black liquor concentrations in the white water system.

b. Spill and Evaporator Boil-Out Storage

Evaporators are periodically "boiled out" to restore efficient operation. The material flushed can be stored in a tank to be slowly returned to the process upon resumption of operation. Also, storage facilities can be supplied to contain weak black liquor, strong black liquor, and recovery plant chemicals and liquors from process upsets for ultimate return to the system or for gradual discharge to the waste water treatment system such that no treatment upset occurs.

c. Efficient Pulp Washing

The efficient recovery of black liquor is predicated upon efficient pulp washing which can be accomplished by multi-stage countercurrent washers. Multi-stage countercurrent washers minimize water usage and result in efficient liquor recoveries.

## NSSC - Sodium Base

a. Non-Polluting Spent Liquor Disposal

Spent liquor disposal can be accomplished by partial evaporation followed by incineration in a fluidized bed reactor or other comparable unit. Efficient liquor disposal is predicated upon good pulp washing efficiencies.

## NSSC - Ammonia Base

a. Non-Polluting Spent Liquor Disposal

Spent liquor disposal can be accomplished by partial evaporation followed by incineration. Efficient liquor disposal is predicated upon good pulp washing efficiencies.

## Kraft - NSSC (cross recovery)

a. Hot Stock Screening

As explained in Section VII, this is a process modification in which the pulp is passed through a fibrolizer to fractionate knots and then through a hot stock screen to remove shives. This sequence avoids the need for dilution of the pulp for screening and subsequent decker sewer losses. This should be accomplished without increasing black liquor concentrations in the white water system.

b. Spill and Evaporator Boil-Out Storage

Evaporators are periodically "boiled out" to restore efficient operation. The material flushed can be stored in a tank to be slowly returned to the process upon resumption of operation. Also, storage facilities can also be supplied to contain weak black liquor, strong black liquor, and recovery plant chemicals and liquors from process upsets for ultimate return to the system or for gradual discharge to the waste water treatment system such that no treatment upset occurs.

c. Efficient Pulp Washing

The efficient recovery of black liquor is predicated upon efficient pulp washing which can be accomplished by multi-stage countercurrent washers. Multi-stage countercurrent washers minimize water usage and result in efficient liquor recoveries.

## Paperboard from Waste Paper

a. Land Disposal of Junk Materials

Extraneous matter found in waste paper, such as metals, plastics, and rags, can be efficiently removed from the process and disposed of in approved landfills.

## All Subcategories (Paper Machines)

a. Water Showers

Fresh water showers used to clean wire, felt, and other machine elements (of both fourdrinier and cylinder machines) can be low-volume and high-pressure; white water showers can be low pressure, high-volume, and self-cleaning.

b. Segregation of White Water Systems

The segregation of white water systems can be designed to permit maximum reuse within the stock preparation/machine systems and in the pulp mill and to permit only low fiber content white water to enter the sewer.

c. Press Water Filtering

A vibrating or centrifugal screen can be employed to remove felt hairs prior to press water reuse.

d. Collection System for Vacuum Pulp Seal Water

Seal water can be collected for partial reuse and/or cascade to or from other water users.

e. Save-all with Associated Equipment

An effective save-all can be employed to recover fibrous and other suspended material which escapes from the paper machine.

f. Gland Water Reduction

Flow control of individual seal water lines to equipment packing glands, or equivalent measures, can be exercised.

## External Treatment

### a. Suspended Solids Reduction

This step involves removal of suspended solids from the raw waste stream. It can incorporate 1) an earthen stilling basin; 2) mechanical clarification and sludge removal; 3) and/or dissolved air flotation. Solids dewatering screens can also be incorporated prior to solids settling as a means of removing coarse solids.

### b. BOD5 Reduction

The treatment system for reduction of BOD5 is biological oxidation with nutrient addition. The treatment system can consist of the activated sludge process (AS), aerated stabilization basins (ASB), and/or storage oxidation ponds (SO).

### c. Biological Solids Removal

The treatment system should provide for removal of biological solids by either mechanical clarifiers, stilling ponds (or a SO following an ASB), or a quiescent zone in an ASB which is beyond the influence of the aeration equipment.

### d. Sludge Disposal

When compatible with other unit processes, sludge disposal can often be carried out in a stilling pond. However, this necessitates periodic dredging, removal, and disposal of solids. Where activated sludge and mechanical clarification are utilized, sludge handling can be accomplished through sludge thickening followed by sludge dewatering and by vacuum filtration or centrifugation, and ultimate solids disposal. Disposal can be accomplished by either sanitary landfilling or incineration. Combustion can be carried either in a sludge incinerator, the power boiler, or the bark boiler in unbleached kraft pulp mill operations.

## RATIONALE FOR THE SELECTION OF BEST PRACTICABLE POLLUTION CONTROL TECHNOLOGY CURRENTLY AVAILABLE

### Age and Size of Equipment and Facilities

There is a wide range, in both size and age, among mills in the subcategories studied. However, internal operations of most older mills have been upgraded, and some of these mills currently operate very efficiently. The technology for upgrading of older mills is well established, and does not vary significantly from mill to mill within a given subcategory. Studies have also shown that waste treatment plant performance does not relate to mill size. Most mills within a subcategory are constructed on a "modular" concept, where key process elements are duplicated as mill size expands. Consequently, there is no significant variation in either the waste water characteristics or in the waste water loading rates between mills of varying sizes.

### Process Change

Application of the best practicable control technology currently available does not require major changes in existing industrial processes for the subcategories studied. The identified in-plant systems representing BPCTCA have previously been installed at most mills and are thus in common use. Incorporation of any additional systems, treatment processes, and control measures can be accomplished in most cases through changes in piping, and through design modifications to existing equipment. Such alterations can be carried out on all mills within a given subcategory.

The in-plant technology to achieve these effluent limitations is practiced and generally in common use within the subcategories under study. The concepts are proven, available for implementation, and applicable to the wastes in question. The waste treatment techniques are also broadly applied within many other industries. The technology identified will necessitate improved monitoring of waste discharges and of waste treatment components on the part of many mills, as well as more extensive training of personnel in operation and maintenance of waste treatment facilities. However, these procedures are commonly practiced in pulp and paper mills and are common practice in many other industries.

### Non-water Quality Environmental Impact

Application of the activated sludge waste treatment process offers a potential for adverse impact upon air quality if dewatered sludges are incinerated. However, proper selection and operation of particulate emission control equipment can minimize this impact. Dredged or dewatered sludges disposed of on land can present an odor problem unless sanitary landfilling techniques are properly instituted.

The technology cited will not create any significant increase in noise levels beyond those observed in well designed municipal wastewater treatment systems which currently are being approved by the Federal government for construction in populated areas. Further, no hazardous chemicals are required as part of this technology.

The greatest proportion of energy consumed will be for pumping and for biological treatment. The total energy requirements for implementation of best available technology for the categories under study are not substantial (less than one per cent) and should not be great enough to warrant concern on either a national or regional basis.

## Cost of Application in Relation to Effluent Reduction Benefits

Based upon the information contained in Section VIII and the Appendices of this report, the total projected costs of BPCTCA reflect an increase of production expenses as shown in Table 60.

Table 60

Cost of Application of BPCTCA (1971 Cost Index)

| Subcategory | Production kkg/day (tons/day) | Total Annual Cost, Incl. Energy | Increase in Costs $/kkg ($/ton) |
|---|---|---|---|
| Unbleached Kraft | 907 (1000) | $2,675,000 | 8.43 (7.65) |
| NSSC-Sodium Base | 227 (250) | $1,194,000 | 15.04 (13.65) |
| NSSC-Ammonia Base | 227 (250) | $375,000* | 4.74 (4.30)* |
| Kraft-NSSC (Cross Recovery) | 907 (1000) | $2,922,000 | 8.60 (7.80) |
| Paperboard from Waste Paper | 91 (100) | $259,000 | 9.53 (8.64) |

*Cost data for internal mill improvements was not available. Thus, these costs reflect only the external treatment identified.

These increases reflect both all internal mill and external waste treatment improvements. They are based on 350 days of production/year except for the paperboard from waste paper subcategory which is based upon 300 days/year. It should be emphasized, however, that most mills have already carried out many of these improvements. Consequently, their increased costs would be less than those shown above.

## Processes Employed

All mills within each subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not significantly alter either the characteristics or the treatability of the wastewater generated.

## RATIONALE FOR SELECTION OF EFFLUENT LIMITATIONS

The determination of the BPCTCA limitations shown in Table 59 were made through the consideration of all available data for the subcategories under study. On consideration of the data contained in Sections III, V, VII, VIII, and in the Appendices of this report, specific mills were selected as "best performers" based upon effluent qualities being achieved by the mills within the subcategories. The mills were selected to be representative of mills within the specific subcategory, and this included an analysis of pollution control technologies utilized by each mill as being practicable for all mills within each subcategory.

The 30 day limitations were essentially determined by using the average of the best performers maximum month of pollutant discharged, as this accounts for variations in the final effluent qualities as affected by such factors as raw waste or extreme climatic conditions. The daily maximum limitations were determined by doubling the 30 day limitations. The factor of two resulted from an analysis of data relating daily maximum to maximum month.

## Unbleached Kraft

Tables 61 and 62 show mills selected as best performers for the unbleached kraft subcategory. The mills were selected as representative of BPCTCA and included are six of seven unbleached kraft mills achieving the best final effluent qualities in the country. The mill achieving the best final effluent quality in this subcategory was mill UK-3, but the mill's external treatment system was judged to be atypical of the subcategory and was thereby not included as a best performer. The treatment system included an ASB followed by a storage oxidation pond with a detention time in excess of 240 days. Storage oxidation ponds are utilized at nearly 50% of unbleached kraft mills and common sizes range up to 60 days detention time. The large land area utilized by mill UK-3 for its storage oxidation pond was judged to be atypical, as the large land areas may not be available at all unbleached kraft mill sites. In addition, it was determined that the BPCTCA included both stages of treatment at the mills utilizing ASBs followed by storage oxidation ponds as discussed in Section VII. Therefore, because of the large land areas necessary for the storage oxidation ponds, the effluent limitations were determined so that a mill with a well designed and operated ASB should be able to achieve effluent qualities comparable to the ASB-storage oxidation pond system.

## TABLE 61

## BEST PERFORMERS

## MILL DATA

## UNBLEACHED KRAFT

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment Detention Times (Days) | | Aeration in HP |
|---|---|---|---|---|---|
| | | | ASB | SO | ASB |
| UK-1 | 1020(1125) | 39.2(9.4) | 7.5 | 0 | 375 |
| UK-2 | 825(909) | 50(12.0) | 18 | 51 | 480 |
| UK-5 | 1201(1324) | 60(14.4) | 10 | 0 | 1500 |
| UK-6 | 732(807) | 64.2(15.4) | 10 | 8 | 1050 |
| UK-7 | 641(707) | 112.6(27.0) | 7.6 | 7 | 1100 |
| UK-8 | 997(1099) | 43.7(10.4) | 0 | 60 | - |
| Ave. | | 51.4 (12.3)* | | | |

*not including UK-7

## TABLE 62

## BEST PERFORMERS

## MILL EFFLUENT DATA

## UNBLEACHED KRAFT

(All values in kg/kkg (lbs/ton) except as noted)

| | Raw Waste | | Final Effluent | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mill | AA BOD5 | AA TSS | AA BOD5 | MM BOD5 | MM BOD5* | AA TSS | MM TSS | MM TSS* |
| UK-1 | 13.5(27) | 10.5(21)** | 1.4(2.8) | 2.3(4.6) | 50 | 4.7(9.4) | 6.1(12.1) | 119 |
| UK-2 | 12.2(24.5) | - | 0.8(1.6) | 1.3(2.7) | 25 | 2.2(4.5) | 3.8(7.6) | 69 |
| UK-5 | 19(38) | 19.5(39) | 2.1(4.3) | 3.1(6.1) | 55 | 5.1(11.2) | 7.1(14.2) | 124 |
| UK-6 | 21.2(42.5) | - | 2.2(4.5) | 3.7(7.4) | 43 | 2.5(5.0) | 3.9(7.9) | 46 |
| UK-7 | - | - | 2.1(4.2) | 3.1(6.2) | 27 | 3.6(7.2) | 4.6(9.3) | 34 |
| UK-8 | 19(38) | - | 2.3(4.7) | 3.3(6.6) | 75 | 2.9(5.9) | 3.5(7.0) | 69 |
| Average | 17(34.0) | 21.5(43) | 1.8(3.7) | 2.8(5.6) | 46 | 3.6(7.2) | 4.8(9.7) | 77 |

* mg/1
**NSM

The BOD$_5$ limitations for unbleached kraft mills were determined by averaging the maximum month of pollutant discharge for the mills shown in Tables 61 and 62. However, the TSS limitations were based on mill UK-1 and not on an average of the best performers' TSS levels. As discussed above, mills using storage oxidation ponds use large land areas not always available at all unbleached kraft mills and since storage oxidation ponds reduce TSS levels below the levels achieved by ASBs, the limitations were based on mill UK-1.

As shown in Table 61, the average flow rate for the best performers was 61,720 liters/kkg (14,800 gal/ton) with a more representative average of 51,290 liters/kkg (12,300 gal/ton) excluding the mill UK-7 flow rate which disproportionately affects the average. The average flow rate for unbleached kraft mills as presented in Table 22 was 52,540 liters/kkg (12,600 gal/ton). Thus, the average of the best performers was very close to the average for all mills in the subcategory. Another source stated the average for the subcategory was 41,700 liters/kkg (10,000 gal/ton) (40) which indicates that the average of the best performers' flow rates was 8,340 liters/kkg (2,000 gal/ton) greater than the average for the subcategory. This may indicate that the mills selected as best performers had less than the average extent of in-plant controls. In addition, the average raw waste BOD$_5$ for the best performers was 17.0 kg/kkg (34 lbs/ton) which is very near the average for the subcategory of 16.9 kg/kkg (33.8 gal/ton). Since the flow rate and the raw waste BOD$_5$ indicate the extent of internal controls applied within mills, the above discussion indicates that the extent of internal controls at the best performers is very near the average for the entire subcategory.

## NSSC-Ammonia Base

Mill N-1 in Tables 44 and 45 which is the one mill which had biological treatment of the two in the subcategory was not selected as representative of BPCTCA. Analysis of the final effluent data as well as data from primary and ASB effluents and analysis of some of the treatment system design paramters showed that the treatment system appeared to be underaerated to adequately reduce the raw waste load. In addition, several operating problems in the treatment system were apparent, such as high levels of TSS (300-400 mg/l) in the ASB influent from the clarifier.

The BOD$_5$ limitations were determined by using the maximum month BOD$_5$ concentration of 100 mg/l for mill NS-2 of the NSSC-sodium base subcategory and the maximum month flow rate for mill N-1. The TSS limitations were determined using the maximum month flow rate for mill N-1 and a TSS concentration of 120 mg/l which has been shown to be achievable by ASB treatment systems in the unbleached kraft and unbleached kraft-NSSC (cross recovery) subcategories.

## NSSC-Sodium Base

Tables 63 and 64 shows the mill selected as the best performer for the NSSC-sodium base subcategory. Mill NS-1 was not included as a best performer because the mill was considered to be an atypical mill. Mill NS-1 spray irrigates the spent cooking liquor whereas the more common practice includes evaporation and incineration of the waste liquor which adds significantly to the raw waste load. Also, mill NS-1 uses waste paper for approximately one third of the furnish whereas mill NS-2 uses about 6%. This can also have some effect on the raw waste load.

The $BOD_5$ limitations were based upon the maximum month of $BOD_5$ discharge from mill NS-2. Mill NS-2 has been experiencing difficulties with sludge bulking from their clarifiers as the maximum month TSS discharge was 18.75 kg/kkg (37.5 lbs/ton) or 428 mg/l. Thus, the TSS limitations were not entirely based on mill NS-2 but was determined by using the maximum monthly flow rate for NS-2 and a TSS concentration of 120 mg/l. The concentration value was demonstrated by ASB treatment systems in the unbleached kraft and unbleached kraft-NSSC (cross recovery) subcategories.

As shown in Table 22, the average flow rate and raw waste $BOD_5$ load for sodium base NSSC mills was 42,950 liters/kkg (10,300 gal/ton) and 25.15 kg/kkg (50.3 lbs/ton), respectively. The flow rate and raw waste $BOD_5$ load for the best performer, NS-2, are 48,790 liters/kkg (11,700 gal/ton) and 31 kg/kkg (62 lbs/ton), respectively. This indicates that excessive internal controls are not needed for all mills to meet the limitations as demonstrated by mill NS-2. Mill NS-2 reduced their higher than average raw waste load to acceptable BPCTCA levels through external treatment.

## Unbleached Kraft-NSSC (Cross Recovery)

Tables 65 and 66 shows mills selected as best performers for the unbleached kraft-NSSC (cross recovery) subcategory. Mill X-2 is not included as the mill discharges a portion of its raw waste to gravel beds for six to nine months per year and thus is an atypical treatment system.

The $BOD_5$ limitations for the unbleached kraft-NSSC (cross recovery) subcategory were determined by averaging the maximum month of pollutant discharged for the mills shown in Table 66. However, the TSS limitations were based on mill X-1 which used an ASB. Mills X-3 and X-4 used two stage treatment systems of ASB-storage oxidation ponds. The rationale for the methodology used in determining the TSS limitations were discussed previously for unbleached kraft mills.

As shown in Tables 65 and 66, the average flow rate and raw waste $BOD_5$ loads for the best performers were 58,380 liters/kkg (14,000 gal/ton) and 20.15 kg/kkg (40.3 lbs/ton), respectively. The flow rate is equal to the subcategory average and the $BOD_5$ raw waste load is higher than

## TABLE 63

## BEST PERFORMERS

## MILL DATA

## NSSC - SODIUM BASE

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment Detention (Days) ASB | Treatment Detention (Days) SO | Aeration in HP ASB | TSS Methods |
|---|---|---|---|---|---|---|
| NS-1 | 336(370) | 44.6(10.7) | 3 | 14 | 515 | SM |
| NS-2 | 521(574) | 48.8(11.7) | 5 | 0 | 1200 | SM |

* Clarifier-ASB-Clarifier
return sludge

## TABLE 64

## BEST PERFORMERS

## MILL EFFLUENT DATA

## NSSC - SODIUM BASE

(All values in kg/kkg (lbs/ton) except as noted)

|  | Raw Waste |  | Final Effluent |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Mill | AA BOD5 | AA TSS | AA BOD5 | MM BOD5 | MM BOD5* | AA TSS | MM TSS | MM TSS* |
| NS-2 | 31(62) | 17.5(35) | 3.2(6.4) | 4.3(8.7) | 97 | 13.3(26.6) | 18.7(37.5) | 424 |

*mg/1

## TABLE 65

## BEST PERFORMERS

## MILL DATA

## UNBLEACHED KRAFT-NSSC (CROSS RECOVERY)

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment Detention Time (Days) ASB | Treatment Detention Time (Days) SO | Aeration in HP ASB | TSS Method |
|---|---|---|---|---|---|---|
| X-1 | 1110(1224) | 57.5(13.8) | 7.5 | 0 | 900 | SM |
| X-3 | 1824(2011) | 43.4(10.4) | 18 | 4 | 1000 | SM |
| X-4 | 1215(1340) | 74.3(17.8) | 11 | 5 | 1060 | SM |
| Ave. |  | 58.4(14.0) |  |  |  |  |

# TABLE 66

## BEST PERFORMERS

## MILL EFFLUENT DATA

## UNBLEACHED KRAFT-NSSC (CROSS RECOVERY)

(All values in kg/kkg (lbs/ton) except as noted)

|  | Raw Waste |  | Final Effluent |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|
| Mill | AA<br>BOD5 | AA<br>TSS | AA<br>BOD5 | MM<br>BOD5 | MM<br>BOD5* | AA<br>TSS | MM<br>TSS | MM<br>TSS* |
| X-1 | 24(48) | 28.5(57) | 2.7(5.5) | 3.5(7.1) | 66 | 5(10) | 6.4(12.8) | 118 |
| X-3 | 16.3(32.6) | 13.4(24.9) | 3.3(6.7) | 4.7(9.5) | 105 | 2.8(5.6) | 3.4(6.9) | 72 |
| X-4 | - | - | 2.7(5.5) | 3.9(7.8) | 51 | 2.9(5.7) | 5.1(10.3) | 69 |
| Ave. | 20.2(40.3) | 20.5(41.0) | 3.0(5.9) | 4.1(8.1) | 74 | 3.6(7.1) | 5.0(10.0) | 86 |

*mg/1
**Primary Treatment Effluent

the subcategory average of 19.4 kg/kkg (38.8 lbs/ton). As described previously, the above comparison of flow rates and raw waste $BOD_5$ loads indicates that the extent of internal controls at the best performers is very near the average for the entire subcategory.

## Paperboard from Waste Paper

Tables 67 and 68 present data from mills selected as best performers in the paperboard from waste paper subcategory. The selected mills have either activated sludge or aerated stabilization basin treatment systems.

The $BOD_5$ and TSS 30-day limitations were based upon the maximum month $BOD_5$ and TSS values for the mills in Table 68. The average $BOD_5$ raw waste load for the mills selected as best performers was 8.5 kg/kkg (16.9 lbs/ton) which is less than the subcategory average of approximately 11.25 kg/kkg (22.5 lbs/ton). Thus, the limitations were adjusted to reflect the higher waste load.

The data presented in Tables 48 and 49 indicates that raw waste $BOD_5$ from paperboard from waste paper mills can be efficiently removed by either activated sludge or aerated stabilization basins treatment systems. The percentage removals for the mills selected as best performers (NOTE - all paperboard from waste paper mills with secondary treatment and available data are included as best performers) average 93% with a range of 85-97.5%. Thus, even though the average $BOD_5$ raw waste load was higher for the subcategory than that for the best performers, the mills with higher than average raw waste loads should be able to meet the limitations through demonstrated efficient treatment.

## All Subcategories: pH Range

The pH range of 6.0-9.0 in receiving waters is satisfactory for aquatic life as specified in the draft document by the National Academy of Sciences (NAS) on *Water Quality Criteria*. Thus, the effluent limitations of pH range 6.0-9.0 were chosen for all subcategories.

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## TABLE 67

## BEST PERFORMERS

## MILL DATA

## PAPERBOARD FROM WASTE PAPER

| Mill | Production-AA kkg/day (tons/day) | Flow-AA kiloliters/kkg (1000 gal/ton) | Treatment | Aeration in HP | TSS Method |
|---|---|---|---|---|---|
| P-15 | 145(160) | 68.4(16.4) | C-ASB | 100 | NSM |
| P-16 | 272(300) | 12.1( 2.9) | C-ASB-C | 300 | SM |
| P-17 | 440(485) | 19.6( 4.7) | ASB-SO | - | SM |
| P-18 | 245(270) | 38.8( 9.3) | C-AS-C | 120 | SM |
| P-19 | 56(62) | 5.0( 1.2) | C-AS-C | - | SM |
| P-20 | 91(100) | 47.5(11.4) | C-ASB-HP | 40 | SM |
| P-21 | 145(160) | 9.5( 2.3) | C-ASB | 120 | SM |
| P-22 | 91(100) | 38.8( 9.3) | ASB-DAF | 60 | SM |
| Ave. | | 30.0( 7.2) | | | |

## TABLE 68

## BEST PERFORMERS

## MILL EFFLUENT DATA

## PAPERBOARD FROM WASTE PAPER

(All values kg/kkg (lb/ton) except as noted)

| | Raw Waste | | Final Effluent | | | | | |
|---|---|---|---|---|---|---|---|---|
| Mill | AA BOD5 | AA TSS | AA BOD5 | MM BOD5 | MM BOD5* | AA TSS | MM TSS | MM TSS* |
| P-15 | 16.2(32.5) | 72.5(145) | 1.6(3.3) | 2.4(4.9) | 52 | 6.3(12.7) | 8.7(17.4) | 223 |
| P-16 | 10(20) | 9(18) | 0.25(0.5) | 0.7(1.4) | 58 | 1.3(2.6) | 3.6(7.3) | 301 |
| P-17 | 6(12) | - | 0.55(1.1) | 1.6(3.2) | 82 | 0.8(1.6) | 2.0(4.0) | 103 |
| P-18 | 5.5(11)** | 35(70)** | 0.15(0.3) | 0.35(0.7) | 09 | 0.9(1.9) | 1.5(3.1) | 40 |
| P-19 | 4(8) | 4.7(9.5) | 0.1(0.2) | 0.15(0.3) | 17 | 1.0(2.0) | 2.1(4.2) | 383 |
| P-20 | 7.5(15) | 6.5(13) | 1.1(2.2) | 1.9(3.8) | 42 | 1.4(2.8) | 2.7(5.4) | 61 |
| P-21 | 9.5(19) | 2.8(5.6) | 0.3(0.6) | 0.7(1.4) | 74 | 0.55(1.1) | 1.7(3.5) | 186 |
| P-22 | 9(18) | 7.5(15) | 1.0(2.0) | 1.2(2.4) | 31 | 1.8(3.6) | 2.9(5.9) | 75 |
| Aves. | 8.5(16.9) | 10.9(21.9) | 0.6(1.3) | 1.1(2.3) | 46 | 1.1(2.2) | 2.4(4.8) | 164 |

*mg/1

** Primary Treatment Effluent

# SECTION X

## BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

### INTRODUCTION

Best available technology economically achievable is to be achieved not later than July 1, 1983. It is not based upon an average of the best performance within a given subcategory under study, but has been determined by identifying the very best control and treatment technology employed by a specific point source within a given subcategory, or by applying technology from other industry areas where it is transferrable.

Consideration was also given to:

a. the age of equipment and facilities involved;

b. the process employed;

c. the engineering aspects of the application of various types of control techniques:

d. process changes;

e. cost of achieving the effluent reduction resulting from application of the technology;

f. non-water quality environmental impact, including energy requirements.

This level of technology emphasizes both in-plant process improvements and external treatment of waste waters. It will, therefore, require existing mills to implement significant internal process changes for water reuse and chemical recovery and recycle as well as to apply more advanced waste treatment processes and other improved internal and external controls in order to meet the effluent limitations. In some cases, the industry may be required to conduct applied research and demonstration studies in order to firmly establish the most economical approach toward meeting the limitations. Such studies on the removal of color and nitrogen, where applicable, will be undoubtedly desirable.

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## EFFLUENT REDUCTION ATTAINABLE THROUGH APPLICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

Based upon the information contained in Sections III through VIII and the appendices of this report, a determination has been made that the point source discharge limitations for each identified pollutant as shown in Table 69 can be obtained through the application of best available technology.

Table 69

BATEA Effluent Limitations

Values in kg/kkg (lbs/ton)

| Subcategory | BOD5 30 Day | BOD5 Daily Max | TSS 30 Day | TSS Daily Max |
|---|---|---|---|---|
| Unbleached Kraft | 1.35 (2.7) | 2.7 (5.4) | 1.85 (3.7) | 3.7 (7.4) |
| NSSC - Ammonia | 3.2 (6.4) | 6.4 (12.8) | 2.6 (5.2) | 5.2 (10.4) |
| NSSC - Sodium | 2.25 (4.5) | 4.5 (9.0) | 2.5 (5.0) | 5.0 (10.0) |
| Unbleached Kraft - NSSC | 1.6 (3.2) | 3.2 (6.4) | 2.1 (4.2) | 4.2 (8.4) |
| Paperboard from Waste Paper | 0.65 (1.3) | 1.3 (2.6) | 0.8 (1.6) | 1.6 (3.2) |

| Subcategory | Color 30 Day | Color Daily Max |
|---|---|---|
| Unbleached Kraft | 10 (20) | 15 (30) |
| NSSC - Ammonia | 75% removal | |
| NSSC - Sodium | 75% removal | |
| Unbleached Kraft - NSSC | 12.5 (25) | 18.75 (37.5) |
| Paperboard from Waste Paper | | |

pH for all subcategories shall be within the range of 6.0 to 9.0

The maximum average of daily values for any 30 consecutive day period should not exceed the 30 day effluent limitations shown above. The maximum for any one day should not exceed the daily maximum effluent limitations shown above. The limitations are in kilograms of pollutant per metric ton of production (pounds of pollutant per short ton of production). Effluents should always be within the pH range of 6.0-9.0.

Production is defined as the annual average production off the machine (air dry tons).

Effluent limitations are needed for nitrogen for NSSC ammonia base mills only. However, no specific limitations have been established because of the extreme lack of meaningful data. Currently, only two such mills exist and preliminary indications are that discharges in the range of 7.5-10.0 kg/kkg (15-20 lbs/ton) can occur. No technology for the removal of nitrogen has been applied within the pulp and paper industry, and only very limited technology has been applied in other industries, especially at the concentrations cited. Extensive studies on effective methods for the removal of nitrogen in these concentrations must be carried out before specific effluent limitations can be established.

The TSS parameter is measured by the technique utilizing glass fiber filter disks as specified in Standard Methods for the Examination of Water and Wastewater, (13th Edition) (1).

The color parameter is measued by the NCASI testing method as described in NCASI Technical Bulletin #253 (2). The above color limitations of 75% removal for both sodium and ammonia base NSSC subcategories will be changed to kilograms of color per metric ton of production (pounds of color per short ton of production) at a later date when the technology has been proven through further development. Color units are to be assumed equal to mg/l in determining kilograms (pounds) of color per metric ton (short ton) of production.

## IDENTIFICATION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

The best available technology economically achievable consists of the best practicable control technology currently available as defined in Section IX of this report. It also includes the following additional internal mill improvements and external advanced waste water treatment practices.

### Internal Controls

Pulping operations of all applicable subcategories will be able to implement modifications and operating procedures for:

a. reuse of fresh water filter backwash;

b. control of spills whereby major pollutional loads bypass the waste water treatment system to a retention basin and are ultimately either reused, gradually discharged into the treatment system, or treated separately;

c. reduction of pulp wash and extraction water without decreasing washing efficiencies;

d. extensive internal reuse of process waters;

e. separation of cooling waters from other waste water streams, and subsequent heat removal and reuse;

f. extensive reduction of gland water spillage.

With the exception of the procedures pertaining to reuse of fresh water filter backwash (a.) and reduction of pulp wash and extraction water (c.), the same modifications and procedures are applicable to and capable of implementation by all paper machine systems, including paperboard from waste paper mills.

## External Treatment

Section IX of the report describes best practicable external control technology currently available. Application of that technology in conjunction with several additional recognized and potential technologies described in Section VII constitutes best available technology economically achievable. The additional external processes applicable to this more advanced technology are as follows:

a. BOD$_5$ Reduction
The treatment system for reduction of BOD$_5$ is biological oxidation with nutrient addition.

b. Suspended Solids Reduction
In addition to the technologies identified in Section IX, suspended solids can be further reduced by mixed media filtration with, if necessary, chemical addition and coagulation.

c. Color Reduction
Color reduction can be achieved by minimum lime treatment for unbleached kraft and kraft - NSSC (cross recovery) mills, and by reverse osmosis for NSSC - sodium base and NSSC-ammonia base mills.

## RATIONALE FOR THE SELECTION OF THE BEST AVAILABLE TECHNOLOGY ECONOMICALLY ACHIEVABLE

### Age and Size of Equipment and Facilities

There is a wide range, in both size and age, among mills in the subcategories studied. However, internal operations of most older mills have been upgraded, and some of these mills currently operate very efficiently. The technology for updating of older mills is well established, and does not vary significantly from mill to mill within a given subcategory. Studies have also shown that waste treatment plant performance does not relate to mill size. Most mills within a subcategory are constructed on a "modular" concept, where key process elements are duplicated as mill size expands. Consequently, there is no significant variation in either the waste water characteristics or in the waste water loading rates, in kilograms per metric ton (in lbs/ton of product), between mills of varying sizes.

### Process Changes

Application of the best available technology economically achievable may require some major changes in existing industrial processes for the subcategories studied. Incorporation of additional systems, treatment processes, and control measures can be accomplished through changes in piping, through design modifications to existing equipment, and through installation of additional equipment. Such alternations can be carried out on all mills within a given subcategory.

### Engineering Aspects of Control Technique Applications

The technology to achieve most of these effluent limitations is either practiced within the pulp and paper industry by an outstanding mill in a given subcategory, or is demonstrated in other industries and transferable. However, sufficient research and pilot work has been carried out on all parameters to demonstrate the feasibility of achieving the limitations after completion of additional study. The technology required for all best available treatment and control systems will necessitate sophisticated monitoring, sampling, and control programs, as well as properly trained personnel.

### Non-water Quality Environmental Impact

Application of the activated sludge waste treatment process offers a potential for adverse impact upon air quality if dewatered sludges are incinerated. However, proper selection and operation of particulate emission control equipment can minimize this impact. Dredged or dewatered sludges disposed of on land can present an odor problem unless sanitary landfilling techniques are properly instituted.

The technology cited will not create any significant increase in noise levels beyond those observed in well designed municipal wastewater treatment systems which currently are being approved by the Federal government for construction in populated areas. Further, no hazardous chemicals are required as part of this technology.

The greatest proportion of energy consumed will be for pumping and for biological treatment. The total energy requirements for implementation of best available technology for the subcategories under study are not substantial and should not be great enough to warrant concern on either a national or regional basis.

## Cost of Application in Relation to Effluent Reduction Benefits

Based upon the information contained in Section VIII and the Appendices of this report, total projected cost of upgrading a mill incorporating best practicable control technology currently available to the level of best available technology economically achievable reflects an increase in production expenses as shown in Table 70 (1971 price index).

Table 70
Cost af Application of BATEA

| Subcategory | Production kkg/day (tons/day) | Total Annual Cost Incl. Energy | Increase in Costs $/kkg ($/ton) |
|---|---|---|---|
| Unbleached Kraft | 907 (1000) | $1,505,000 | 4.74 (4.30) |
| NSSC-Sodium Base | 227 (250) | $465,000 | 5.85 (5.31) |
| NSSC-Ammonia Base | 227 (250) | $383,000 | 4.83 (4.38) |
| Kraft-NSSC | 907 (1000) | $1,645,000 | 5.18 (4.70) |
| Paperboard from Waste Paper | 91 (100) | $35,000 | 1.29 (1.17) |

These increases reflect both all internal mill and external waste treatment improvements, with the exception of nitrogen removal for NSSC ammonia base mills. Sufficient data were not available on this parameter. The increases are based on 350 days of production per year except for the paperboard from waste paper subcategory which is based upon 300 days per year.

## Processes Employed

All mills within each subcategory studied utilize the same basic production processes. Although there are deviations in equipment and production procedures, these deviations do not significantly alter either the characteristics or the treatability of the wastewater generated.

## RATIONALE FOR DEVELOPMENT OF BATEA EFFLUENT LIMITATIONS GUIDELINES

The rationale used in developing the BATEA effluent limitations for BOD5, TSS, pH, and Color is discussed below.

The BOD5 BATEA limitations were determined by applying the estimated BOD5 reductions for each applicable external control technology to the projected BOD5 raw waste load for mills in 1983 as estimated by the application of the identified internal controls. The estimated efficiencies of BOD5 removal for each external treatment technology utilized in determining the BATEA limitations are shown below:

| External Technology | BOD5 Removal |
|---|---|
| Color Removal-minimum lime | 15% |
| Biological Treatment | 90%* |
| Coagulation & Filtration | 15% |

*95% used for Paperboard from Waste Paper Subcategory

The above percentage reductions were applied to the projected raw waste loads (estimated by application of the internal controls described previously) as applicable to each subcategory as shown in Table 71. It should be noted that the BOD5 attributable to the application of reverse osmosis for color removal was not estimated for NSSC mills in the calculations. The above discussions describe the expected performances on an annual basis. To determine the 30-day limitations, a ratio of maximum month to annual average of 1.5 was applied. It is expected that variations in final effluent qualities will be less than those experienced by mills with BPCTCA of approximately 1.5 - 1.8 (maximum month to annual average), as the BATEA should reduce the variations in treatment efficiencies.

The TSS limitations were determined by using the BPCTCA limitations as a base and applying the estimated TSS reductions as estimated by the application of the BATEA. The calculations took into account the relationship of TSS in the final effluent from biological treatment systems and the BOD5 in the raw waste. Generally, the TSS levels are directly affected by the BOD5 raw waste load, as the TSS in biological treatment system effluents generally are biological organisms generated in the removal of BOD5. Also, the TSS limitations were based on the application of the technology of coagulation and filtration which was conservatively estimated to remove 60% of TSS from the biological treatment effluent.

Analysis of the mill data showed that the common ratio of maximum day to maximum month was approximately 2.0 for both BOD5 and TSS. Thus, the daily maximum limitations were determined by applying 2.0 to the 30-day limitations.

## TABLE 71

## APPLICABLE EXTERNAL TECHNOLOGIES IN DEVELOPMENT OF BATEA LIMITATIONS

| Subcategory | Raw Waste kg/kkg (lbs/ton) | Color Removal | Biological Treatment |
|---|---|---|---|
| Unbleached Kraft | 12.5(25) | X | X |
| NSSC-Sodium | 17.5(35) | | X |
| NSSC-Ammonia | 25(50) | | X |
| Kraft-NSSC | 15(30) | X | X |
| Paperboard-Waste Paper | 10(20) | | X |

## pH Range

The pH range of 6.0-9.0 in receiving waters is satisfactory for aquatic life as specified in the draft document by the National Academy of Sciences (NAS) on Water Quality Criteria. Thus, the effluent limitations of pH range 6.0-9.0 were chosen for all subcategories.

## Color

### Unbleached Kraft

Minimum lime treatment systems have demonstrated that consistent effluent levels of 125-150 CU can be attained independent of influent color levels. Massive lime treatment systems have achieved effluent levels of 200-250 CU. Using the BATEA and NSPS water usage of 37,560 liters/kkg (9,000 gal/ton) and demonstrated achievable color levels of 250 CU, the 30-day limitations were determined. The daily maximum was determined by applying 1.5 to the 30-day limitations as the daily values generally have been approximately 50% higher than the long term average.

### Kraft - NSSC (Cross Recovery)

The levels of color being achieved by minimum lime treatment systems vary from near 100 CU to near 500 CU with the typical range between 300 to 380 CU. Based upon the projected effluent flow rate of 33,360 liters/kkg (8,000 gal/ton) and 380 CU, the effluent limitations were determined. The daily maximum was determined by applying 1.5 to the 30-day limitations as the daily values generally have been approximately 50% higher than the long term average.

### NSSC - Ammonia Base, Sodium Base

Reverse osmosis has not yet been demonstrated at full mill scale. However, pilot scale studies have indicated that at least 75% reduction of color should be achievable. Thus, the effluent limitations were chosen as 75% removal of color.

# SECTION XI

# NEW SOURCE PERFORMANCE STANDARDS

## INTRODUCTION

This level of technology is to be achieved by new sources. The term "new source" is defined in the Act to mean "any source, the construction of which is commenced after the publication of proposed regulations prescribing a standard of performance." Such commencement of construction can occur within the near future, certainly before either the 1977 or 1983 compliance dates for either best practicable or best achievable technologies.

Consideration has also been given to:

a. The type of process employed and process changes;

b. Operating methods;

c. Batch as opposed to continuous operations;

d. Use of alternative raw materials and mixes of raw materials;

e. Use of dry rather than wet processes (including substitution of recoverable solvents for water);

f. Recovery of pollutants as by-products;

## EFFLUENT REDUCTIONS ATTAINABLE THROUGH THE APPLICATION OF NEW SOURCE PERFORMANCE STANDARDS

Based upon the information contained in Sections III through VIII and in the appendices of this report, a determination has been made that the point source discharge standards for each identified pollutant shown in Table 72 can be obtained through the application of proper technology.

## Table 72

### New Source Performance Standards

### Values in kg/kkg (lbs/ton)

| Subcategory | BOD5 30 Day | BOD5 Daily Max | TSS 30 Day | TSS Daily Max |
|---|---|---|---|---|
| Unbleached Kraft | 1.55 (3.1) | 3.1 (6.2) | 3.75 (7.5) | 7.5 (15.0) |
| NSSC - Ammonia | 3.75 (7.5) | 7.5 (15.0) | 3.75 (7.5) | 7.5 (15.0) |
| NSSC - Sodium | 2.6 (5.2) | 5.2 (10.4) | 3.85 (7.7) | 7.7 (15.4) |
| Unbleached Kraft - NSSC | 1.9 (3.8) | 3.8 (7.6) | 4.0 (8.0) | 8.0 (16.0) |
| Paperboard from Waste Paper | 0.75 (1.5) | 1.5 (3.0) | 2.0 (4.0) | 4.0 (8.0) |

| Subcategory | Color 30 Day | Color Daily Max |
|---|---|---|
| Unbleached Kraft | 10 (20) | 15 (30) |
| NSSC - Ammonia | - | - |
| NSSC - Sodium | - | - |
| Unbleached Kraft - NSSC | 12.5 (25) | 18.75 (37.5) |
| Paperboard from Waste Paper | - | - |

pH for all subcategories shall be within the range of 6.0 to 9.0

The maximum average of daily values for any 30 consecutive day period should not exceed the 30 day standards shown above. The maximum for any one day should not exceed the daily maximum standards shown above. The standards are in kilograms of pollutant per metric ton of production (pounds of pollutant per short ton of production). Effluents should always be within the pH range of 6.0 to 9.0.

Production is defined as the annual average production off the machine (air dry tons).

The TSS parameter is measued by the technique utilizing glass fiber filter disks as specified in Standard Methods for the Examination of Water and Wastewater, (13th Edition) (1).

The color parameter is measued by methods described in NCASI Technical Bulletin #253 (2). Color units are to be assumed equal to mg/l in determing kilograms (pounds) of color per metric ton (short ton) of production.

## IDENTIFICATION OF TECHNOLOGY TO ACHIEVE THE NEW SOURCE PERFORMANCE STANDARDS

The technology to achieve the new source performance standards should consist of the best available control technology economically achievable as described in Section X with the following changes:

### External Controls

Coagulation and filtration is not included for any of the subcategories.

Color reduction for NSSC - sodium base and NSSC - ammonia base mills is not included.

## RATIONALE FOR SELECTION OF TECHNOLOGY FOR NEW SOURCE PERFORMANCE STANDARDS

### Type of Process Employed and Process Changes

No radical new in-plant processes are proposed as a means of achieving new source performance standards for the subcategories studied. The internal control technologies which are identified have all been demonstrated in mills within the subcategories under study.

### Operating Methods

Significant revisions in operating methods, both in-plant and at the waste water treatment facility, will be necessary. However, these improvements are not beyond the scope of well-trained personnel, and are currently being practiced. The primary areas of operational change will pertain to required activities for recycle, reuse, and spill control, as well as for optimal performance of waste water treatment facilities.

## Batch as Opposed to Continuous Operations

For the subcategories studied, it was determined that batch as opposed to continuous operations are not a significant factor in waste load characteristics and no additional control of pollutants could be achieved through the use of one type process over the other.

## Use of Alternative Raw Materials and Mixes of Raw Materials

The raw materials requirements for a given mill in each of the subcategories studied do vary, depending upon supply and demand, desired end product, and other conditions. However, alteration of raw materials as a means of reducing pollutants is not considered feasible over the long term even though such a change could possibly realize benefits of short duration in a given instance. The one possible exception to this could be alternatives for the NSSC-ammonia base mills if an effective and economical method for removal of nitrogen does not become available through further study.

## Use of Dry Rather than Wet Processes (Including Substitution of Recoverable Solvents for Water)

For the subcategories studied, it was determined that technology for dry pulping or papermaking processes does not exist nor is it in a sufficiently viable experimental stage to be considered here.

## Recovery of Pollutants as Byproducts

As discussed in Section VIII of this report, recovery of some potentially polluting materials as by-products is economically feasible and commonly practiced in unbleached kraft mills. In addition, ash from incineration of sodium base NSSC spent liquor is sold to kraft mills to be used as make-up chemical which avoids the necessity for its disposal. It is anticipated that these performance standards will motivate increased research on recovering other materials for by-product sale the recovery of which is not presently economically feasible.

## Cost of Application in Relation to Effluent Reduction Benefits

Based upon the information contained in Section VIII and the Appendices of this report, the total projected cost of NSPS technology reflects an increase in production expenses as shown in Table 73 (1971 price index).

Table 73
Cost of Application of NSPS

| Subcategory | Production kkg/day (tons/day) | Total Annual Cost Incl. Energy | Increase in Costs $/kkg ($/ton) |
|---|---|---|---|
| Unbleacned Kraft | 907 (1000) | $2,198,000 | $6.92 (6.28) |
| NSSC-Sodium | 227 (250) | $402,000 | $5.06 (4.59) |
| NSSC-Ammonia | 227 (250) | $526,000 | $6.63 (6.01) |
| Kraft-NSSC | 907 (1000) | $2,264,000 | $7.13 (6.47) |
| Paperboard from Waste Paper | 91 (100) | $103,000 | $3.78 (3.43) |

These increases reflect both all internal and external identified control technologies. The increases are based on 350 days of production per year except for paperboard from waste paper which is based on 300 days per year.

## RATIONALE FOR DEVELOPMENT OF NEW SOURCE PERFORMANCE STANDARDS

The New Source Performance Standards are based upon the best demonstrated control technology processes and operating methods as determined for the subcategories under study. The standards were developed by essentially the same methodology as described for the BATEA limitations. The major differences, shown in Table 74, was not including coagulation and filtration for TSS reduction and reverse osmosis for color reduction in the identified technologies for new sources, as these were determined to be not completely demonstrated in the pulp and paper industry.

TABLE 74

APPLICABLE EXTERNAL TECHNOLOGIES IN DEVELOPMENT OF STANDARDS FOR NEW SOURCES

| Subcategory | Raw Waste kg/kkg (lbs/ton) | Color Removal | Biological Treatment |
|---|---|---|---|
| Unbleached Kraft | 12.5(25) | X | X |
| NSSC-Sodium | 17.5(35) | | X |
| NSSC-Ammonia | 25(50) | | X |
| Kraft-NSSC | 15(30) | X | X |
| Paperboard-Waste Paper | 10(20) | | X |

# SECTION XII

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## SECTION XIV

## GLOSSARY

**Act**

Federal Water Pollution Control Act, as amended in 1972.

**Bark**

The protective covering of a tree.

**Barking**

Removal of bark from logs in a wet or dry process.

**Black Liquor**

Spent liquor recovered from a kraft digester up to the point of the liquor being incinerated in the recovery plant.

**Bleaching**

The brightening and delignification of pulp by addition of chemicals such as chlorine.

**Boil-Out**

A procedure, usually utilizing heat and chemicals, to clean process equipment such as evaporators, heat-exchangers and pipelines.

**Broke**

Partly or completely manufactured paper that does not leave the machine room as salable paper or board; also paper damaged in finishing operations such as rewinding rolls, cutting, and trimming.

**Cellulose**

The fibrous constituent of trees which is the principal raw material of paper and paperboard.

**Chemi-Mechanical Pulp**

Pulp produced mechanically by grinding or refining after presoaking of wood with caustic soda/sodium sulfite solution.

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**Chest**

A tank used for storage of wet fiber or furnish.

**Chips**

Small pieces of wood used to make pulp.

**Coatings**

Materials such as clay, starch, alum, synthetic adhesives, etc., applied to the surface of paper or paperboard to impart special characteristics.

**Color Unit**

A measure of color concentration in water using NCASI methods.

**Consistency**

A weight percent of solids in a solids-water mixture used in the manufacture of pulp or paper.

**Cooking**

Heating of wood, water, and chemicals in a closed vessel under pressure to a temperature sufficient to separate fibrous portion of wood by dissolving lignin and other nonfibrous constituents.

**Cooking Liquor**

The mixture of chemicals and water used to dissolve lignin in wood chips.

**Countercurrent Washing**

Pulp washing in which fresh water is added only at the last stage and the effluent from this stage is then used as wash water for the previous stages.

**Decker**

A mechanical device used to remove water or spent cooking liquor from pulp.

**Denitrification**

Bacterial mediated reduction of nitrate to nitrite. Other bacteria may act on the nitrite reducing it to ammonia and finally N2 gas. This reduction of nitrate occurs under anaerobic conditions. The nitrate replaces oxygen as an election acceptor during the metabolism of carbon compounds under anaerobic conditions.

**Digester**

A pressure vessel used to cook wood chips in the presence of cooking liquor and heat.

**Dregs**

The inert rejects from the green liquor clarifier of a pulp mill.

**External Treatment**

Technology applied to raw waste streams to reduce pollutant levels.

**Extraction Water**

Water removed during a pulp manufacturing process.

**Felt**

An endless belt of wool or plastic used to convey and dewater the sheet during the papermaking process.

**Fiber**

The cellulosic portion of the tree used to make pulp, paper and paperboard.

**Furnish**

The mixture of fibers and chemicals used to manufacture paper.

**Gland**

A device utilizing a soft wear-resistant material used to minimize leakage between a rotating shaft and the stationary portion of a vessel such as a pump.

**Gland Water**

Water used to lubricate a gland. Sometimes called "packing water."

**Grade**

The type of pulp or paper product manufactured.

## Green Liquor

Liquor made by dissolving chemicals recovered from the kraft process in water and weak liquor preparatory to causticizing.

## In Plant Measures

Technology applied within the manufacturing process to reduce or eliminate pollutants in the raw waste water. Sometimes called "internal measures" or "internal controls".

## Nitrification

Bacterial mediated oxidation of ammonia to nitrite. Nitrite can be further oxidized to nitrate. These reactions are brought about by only a few specialized bacterial species. Nitrosomonias sp. and Nitrococcus sp. oxidize ammonia to nitrite which is oxidized to nitrate by Nitrobacter sp.

## Nitrogen fixation

Biological nitrogen fixation is carried on by a select group of bacteria which take up atmospheric nitrogen ($N2$) and convert it to amine groups or for amino acid synthesis.

## Packing Water

See Gland water.

## Pulp

Cellulosic fibers after conversion from wood chips.

## Pulper

A mechanical device resembling a large-scale kitchen blender used to separate fiber bundles in the presence of water prior to papermaking.

## Rejects

Material unsuitable for pulp or papermaking which has been separated in the manufacturing process.

## Sanitary Landfill

A sanitary landfill is a land disposal site employing an engineered method of disposing of solid wastes on land in a manner that minimizes environmental hazards by spreading the wastes in thin layers, compacting the solid wastes to the smallest practical volume, and applying cover material at the end of each operating day.

**Save-all**

A mechanical device used to recover papermaking fibers and other suspended solids from a waste water or process stream.

**Screenings**

Rejects from a pulp mill separating device such as a screen.

**Shives**

Bundles of fiber which have not been defiberized.

**Spent Cooking Liquor**

Cooking liquor after the digesting operation, containing lignaceous as well as chemical materials.

**Stock**

Wet pulp with or without chemical additions.

**Suction Box**

A rectangular box with holes or slots on its top surface, used to suck water out of a felt or paper sheet by the application of vacuum.

**Suction Couch Roll**

A rotating roll containing holes through which water is sucked out of a paper sheet on a fourdrinier machine, by the application of vacuum.

**Sulfidity**

Sulfidity is a measure of the amount of sulfur in kraft cooking liquor. It is the percentage ratio of NaS, expressed as NaO, to active alkali.

**Virgin Wood Pulp** (or fiber)

Pulp made from wood, as contrasted to waste paper sources of fiber.

**White Liquor**

Liquors made by causticizing green liquors; cooking liquor.

**White Water**

Water which drains through the wire of a paper machine which contains fiber, filler, and chemicals.

## Wire

An endless moving belt made of metal or plastic, resembling a window screen, upon which a sheet of paper is formed on a fourdrinier machine.

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## APPENDIX I

## MILLS LISTED BY SUBCATEGORY

### UNBLEACHED KRAFT MILLS

Georgia Kraft Co.
Mahrt, Alabama

Union Camp Corp
Montgomery, Alabama

MacMillan Bloedel United, Inc.
Pine Hill, Alabama

Gulf States Paper Corp.
Tuscaloosa, Alabama

International Paper Co.
Camden, Arkansas

Arkansas Kraft Corp.
Morrilton, Arkansas

Weyerhaeuser Co.
Pine Bluff, Arkansas

Alton Box Board Co.
Jacksonville, Florida

St. Regis Paper Co.
Jacksonville, Florida

Georgia Kraft Co.
Krannert, Georgia

Georgia Kraft Co.
Macon, Georgia

Continental Can Co., Inc.
Port Wentworth, Georgia

Interstate Paper Corp.
Riceboro, Georgia

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Owens-Illinois, Inc.
Valdosta, Georgia

Unijax, Inc.
Elizabeth, Louisiana

Pineville Kraft Corp.
Pineville, Louisiana

St. Regis Paper Co.
Monticello, Mississippi

International Paper Co.
Vicksburg, Mississippi

Albemarle Paper Co.
Roanoke Rapids, North Carolina

International Paper Co.
Gardiner, Oregon

Weyerhaeuser Co.
Springfield, Oregon

Georgia-Pacific Corp.
Toledo, Oregon

Westvaco Corp.
Charleston, South Carolina

South Carolina Industries, Inc.
Florence, South Carolina

Tennessee River Pulp & Paper Co.
Counce, Tennessee

Owens-Illinois, Inc.
Orange, Texas

Crown Zellerbach Corp.
Port Townsend, Washington

## KRAFT-NSSC MILLS

Great Northern Paper Co.
Cedar Springs, Georgia

Union Camp Corp.
Savannah, Georgia

International Paper Co.
Bastrop, Louisiana

Continental Can Co.
Hodge, Louisiana

Continental Can Co.
Hopewell, Virginia

Container Corp. of America
Fernandina Beach, Florida

Olinkraft, Inc.
West Monroe, Louisiana

Weyerhaeuser Co.
Valliant, Oklahoma

Western Kraft Corp.
Albany, Oregon

Boise Cascade Corp.
Wallula, Washington

## NSSC MILLS (SODIUM BASE)

Weston Paper and Mfg. Co.
Terre Haute, Indiana

Celotex Corp.
Dubuque, Iowa

Consolidated Packaging Corp.
Fort Madison, Iowa

Wescor Corp.
Hawesville, Kentucky

Hoerner Waldorf Corp.
Ontonagon, Michigan

Menasha Corp.
Otsego, Michigan

Hoerner Waldorf Corp.
St. Paul, Minnesota

Container Corp. of America
Circleville, Ohio

Stone Container Corp.
Coschocton, Ohio

Celotex Corp.
Sunbury, Pennsylvania

Mead Corp.
Harriman, Tennessee

Mead Corp.
Lynchburg, Virginia

Green Bay Packaging, Inc.
Green Bay, Wisconsin

Menasha Corp.
North Bend, Oregon

## NSSC MILLS (AMMONIA BASE)

Mead Corp.
Sylva, North Carolina

Inland Container Corp.
New Johnsonville, Tennessee

## PAPERBOARD FROM WASTE PAPER MILLS IN THE U.S.

National Gypsum Co.
Anniston, Alabama

Stone Container Corp.
Mobile, Alabama

Sonoco Products Co.
City of Industry, California

Container Corp. of America
Los Angeles, California

Fontana Papers Inc.
Fontana, California

Federal Paper Board Co., Inc.
Los Angeles, California

Fiberboard Corp.
Los Angeles, California

L.A. Paper Box & Board Mills
Los Angeles, California

America Forest Products Corp.
Newark, California

Western Kraft Corp.
Port Hueneme, California

Sonoco Products Co.
Richmond, California

Kaiser Gypsum Co.
San Leandro, California

Container Corp. of America
Santa Clara, California

Georgia-Pacific Corp.
Santa Clara, California

Speciality Paper Mills Inc.
Santa Fe Springs, California

U.S. Gypsum Co.
South Gate, California

Fibreboard Corp.
Stockton, California

Fibreboard Corp.
Vernon, California

Packaging Corp. of America
Denver, Colorado

Colonial Board Co.
Manchester, Connecticut

Robertson Paper Box Co.
Montville, Connecticut

Federal Paper Board Co., Inc.
New Haven, Connecticut

Simkins Industries, Inc.
New Haven, Connecticut

Federal Paper Board Co., Inc.
Versailles, Connecticut

Container Corp. of America
Wilmington, Delaware

U.S. Gypsum Co.
Jacksonville, Florida

Simkins Industries, Inc.
Miami, Florida

Sonoco Products Co.
Atlanta, Georgia

Austell Box Board Corp.
Austell, Georgia

Alton Box Board Co.
Cedartown, Georgia

Alton Box Board Co.
Alton, Illinois

Aurora Paperboard Co.
Aurora, Illinois

Container Corp. of America
Chicago, Illinois

Prairie State Paper Mills
Joliet, Illinois

Nabisco, Inc.
Marseilles, Illinois

Federal Paper Board Co., Inc.
Morris, Illinois

Quaker Oats Co.
Pekin, Illinois

Packaging Corp. of America
Quincy, Illinois

Sonoco Products Co.
Rockton, Illinois

Kieffer Paper Mills, Inc.
Brownstown, Indiana

Container Corp. of America
Carthage, Indiana

Clevepak Corp.
Eaton, Indiana

Beveridge Paper Co.
Indianapolis, Indiana

Alton Box Board Co.
Lafayette, Indiana

Vincennes Paper Mills Inc.
Vincennes, Indiana

Container Corp. of America
Wabash, Indiana

Packaging Corp. of America
Tama, Iowa

Packaging Corp. of America
Hutchinson, Kansas

Lawrence Paper Co.
Lawrence, Kansas

Yorktowne Paper Mills of Maine, Inc.
Gardiner, Maine

Keys Fibre Co.
Waterville, Maine

Chesapeake Paper Board Co.
Baltimore, Maryland

Simkins Industries, Inc.
Cantonsville, Maryland

Simkins Industries, Inc.
Ilchester, Maryland

Federal Paper Board Co., Inc.
Whitehall, Maryland

Bird and Son, Inc.
East Wapole, Massachusetts

Haverhill Paperboard Corp.
Haverhill, Massachusetts

Sonoco Products Co.
Holyoke, Massachusetts

Perket Folding Box Corp.
Hyde Park, Massachusetts

Lawrence Paperboard Corp.
Lawrence, Massachusetts

Newark Boxboard Co.
Natick, Massachusetts

West Dudley Paper Co.
West Dudley, Massachusetts

Michigan Carton Co.
Battle Creek, Michigan

Simplex Industries
Constantine, Michigan

Packaging Corp. of America
Grand Rapids, Michigan

Brown Co.
Kalamazoo, Michigan

National Gypsum Co.
Kalamazoo, Michigan

Consolidated Packaging Corp.
Monroe, Michigan

Time Container Corp.
Monroe, Michigan

Union Camp Corp.
Monroe, Michigan

Mead Corp.
Otsego, Michigan

Simplex Industries Inc.
Palmyra, Michigan

Rockford Paper Mills, Inc.
Rockford, Michigan

Weyerhaeuser Co.
White Pigeon, Michigan

U.S. Gypsum Co.
N. Kansas City, Missouri

Brown Products
Nashua, New Hampshire

Hoague Sprague Div., USM Corp.
West Hopkinton, New Hampshire

MacAndrews & Forbes Co.
Camden, New Jersey

U.S. Gypsum Co.
Clarks, New Jersey

Whippany Paper Board Co.
Clifton, New Jersey

Georgia-Pacific Corp.
Delair, New Jersey

National Gypsum Co.
Garwood, New Jersey

Boyle Co.
Jersey City, New Jersey

Davey Co.
Jersey City, New Jersey

National Gypsum Co.
Millington, New Jersey

Newark Boxboard Co.
Newark, New Jersey

Morris Paper Board Co.
Patterson, New Jersey

Lowe Paper Co.
Ridgefield, New Jersey

Lincoln Paper Mills, Inc.
Ridgefield Park, New Jersey

Whippany Paper Board Co.
Whippany, New Jersey

Sonoco Products Co.
Amsterdam, New York

Latex Fiber Industries
Beaver Falls, New York

Laxtex Fiber Industries
Brownville, New York

Georgia Pacific Corp.
Buchanan, New York

Climax Mfg. Co.
Carthage, New York

Brown Co.
Castleton-on-Hudson, New York

Columbia Corp.
Chatham, New York

Cornwall Paper Mills Co.
Cornwall, New York

Sealright, Inc.
Fulton, New York

Beaverboard Co., Inc.
Lockport, New York

Martisco Paper Co., Inc.
Marcellus, New York

Columbia Corp.
North Hoosick, New York

Boundary Paper Mills, Inc.
North Tonawanda, New York

U.S. Gypsum Co.
Oakfield, New York

Clevepak Corp.
Piermont, New York

Federal Paper Board Co., Inc.
Piermont, New York

Cottrell Paper Co. Inc.
Rock City Falls, New York

Foster Paper Co. Inc.
Utica, New York

Warrensburg Board & Paper Corp.
Warrensburg, New York

Columbia Corp.
Waloomsac, New York

Carolina Paper Board Corp.
Charlotte, North Carolina

Federal Paper Board Co.
Roanoke Rapids, North Carolina

Crown Zellerbach Corp.
Baltimore, Ohio

Tecumseh Corrugated Box Co.
Brecksville, Ohio

Container Corp. of America
Cincinnati, Ohio

Mead Corp.
Cincinnati, Ohio

St. Regis Paper Co.
Coschocton, Ohio

Stone Container Corp.
Franklin, Ohio

U.S. Gypsum Co.
Gypsum, Ohio

Tecomseh Corrogated Box Co.
Jaite, Ohio

Loroco Industries, Inc.
Lancaster, Ohio

Diamond International Corp.
Lockland, Ohio

Chipboard Inc.
Massilon, Ohio

Massilon Paper Co.
Masilon, Ohio

Interstate Folding Box Co.
Miamisburg, Ohio

Continental Can Co. Inc.
Middleton, Ohio

Diamond International Corp.
Middletown, Ohio

Middletown Paperboard Co.
Middletown, Ohio

Sonoco Products Co.
Munroe Falls, Ohio

Packaging Corp. of America
Rittman, Ohio

Federal Paperboard Co., Inc.
Steubenville, Ohio

Toronto Paperboard Co.
Toronto, Ohio

National Gypsum Co.
Pryor, Oklahoma

Georgia - Pacific Corp.
Pryor, Oklahoma

Packaging Corp. of America
Delaware Water Gap, Pennsylvania

Brandywine Paper Corp.
Downingtown, Pennsylvania

Sonoco Products Co.
Downingtown, Pennsylvania

American Paper Products Co.
Eden, Pennsylvania

American Paper Products Co.
Lancaster, Pennsylvania

Henry Molded Products Inc.
Lebanon, Pennsylvania

National Gypsum Co.
Milton, Pennsylvania

Connelly Containers Inc. of Philadelphia
Philadelphia, Pennsylvania

Container Corp. of America
Philadelphia, Pennsylvania

Crown Paper Board Co.
Philadelphia, Pennsylvania

Newman & Co., Inc.
Philadelphia, Pennsylvania

Beacon Paper Co.
Reading, Pennsylvania

Federal Paper Board Co., Inc.
Reading, Pennsylvania

Interstate Intercorr Corp.
Reading, Pennsylvania

Whippany Paper Board Co.
Riegelsville, Pennsylvania

Packaging Corp. of America
Stroudsburg, Pennsylvania

Westvacc Corp.
Williamsburg, Pennsylvania

St. Regis Paper Co.
York, Pennsylvania

Yorktowne Paper Mills, Inc.
York, Pennsylvania

Carotell Paper Board Corp.
Taylors, South Carolina

Container Corp. of America
Chattanooga, Tennessee

Tennessee Paper Mills, Inc.
Chattanooga, Tennessee

Sonoco Products Co.
Newport, Tennessee

TXI Paper Products, Inc.
Dallas, Texas

U.S. Gypsum Co.
Galena Park, Texas

Federal Paper Board Co. Inc. (2 mills)
Richmond, Virginia

Container Corp. of America
Tacoma, Washington

Fibreboard Corp.
Sumner, Washington

Halltown Paper Board Co.
Halltown, West Virginia

Banner Fibreboard Co.
Wellsburg, West Virginia

Beloit Box Board Co.
Beloit, Wisconsin

Menasha Corp.
Menasha, Wisconsin

St. Regis Paper Co.
Milwaukee, Wisconsin

U.S. Paper Mills Corp.
West De Pere, Wisconsin

## Appendix II

## NPDES DATA

## UNBLEACHED KRAFT LINERBOARD MILLS

| Mill No. | Tons/ Day | Treatment C | Treatment L | Treatment ASB | Treatment AS | Treatment SO | Treatment SS | Treatment CD | Flow G/Ton x1000 | Discharge TSS #/Ton | Discharge BOD #/Ton |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 650 | | | | | X | | | 16.7 | 1.1 | 0.4 |
| 2 | 450 | | | | | X | | | 21.0 | 1.0 | 0.9 |
| 3 | 900 | X | | X | | | | | 10.0 | 1.67 | 1.25 |
| 4 | 940 | | | X | | | | X | 21.0 | 2.8 | 1.3 |
| 5 | 1000 | X | | X | | | | X | 17.0 | 1.2 | 1.5 |
| 6 | 1000 | X | | X | | | | | 11.75 | 5.0 | 3.7 |
| 7 | 900 | | X | | | X | | | 23.0 | 3.4 | 4.0 |
| 8 | 206 | X | | X | | | | | 17.5 | 7.6<br>10.0* | 11.5<br>4.0* |
| 9 | 1150 | X | | X | | | | | 14.7 | 5.8 | 2.3 |
| 10 | 1670 | | X | X | | | L | | 10.1 | 36.0 | 6.5 |
| 11 | 1200 | | X | | | X | L | X | 7.1 | 0.56 | 3.2 |
| 12 | 1565 | | X | X | | | | | 10.4 | 16.8 | 10.1 |
| 13 | 850 | X | | X | | | L | | 13.7 | 5.9 | 5.2 |
| 14 | 600 | | | | | | | | 23.3 | 34.2 | 42.5 |
| 15 | 1000 | | X | | | | | | 14.5 | 24.1 | 27.2 |
| 16 | 750 | | X | | | X | | | 11.2 | 10.3 | 19.6 |
| 17 | 625 | | X | | | | | | 9.1 | 35.5 | 56.1 |
| 18 | 650 | X | | X | | | | | 29.5 | 34.8 | 9.4 |
| 19 | 1670 | X | | X | | | | | 10.1 | 3.7 | 6.5 |
| 20 | 1000 | X | | | | | | | 13.0 | 20.8 | 30.3 |

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### Unbleached Kraft Linerboard Mills - Cont'd.

| Mill No. | Tons/ Day | Treatment | | | | | | | Flow G/Ton x1000 | Discharge | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | L | ASB | AS | SO | SS | CD | | TSS #/Ton | BOD #/Ton |
| 21 | 410 | X | | | | | | | 75.8 | 48.5 | 56.6 |
| 22 | 1450 | X | | | | | L | | 6.3 | 2.9 | 8.0 |
| 23 | 1250 | | | | | | | | 30.4<br>40.0* | 328 | 368 |

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### NEUTRAL SULFITE SEMI-CHEMICAL MILLS (SODIUM BASE)

| Mill No. | Tons/ Day | Treatment | | | | | | | Flow G/Ton x1000 | Discharge | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | L | ASB | AS | SO | SS | CD | | TSS #/Ton | BOD #/Ton |
| 1 | 335 | | | X | | | | | 12.9 | 8.3 | 15.5 |
| 2 | 150 | | | | | | | | 14.9 | 61.6 | 90.0 |
| 3 | 240 | | | | | | | | | N/A | N/A |
| 4 | 550 | | | | | | | | 5.0 | N/A | N/A |
| 5 | 525 | X | | X | | | | | 24.4 | 33.5 | 30.7<br>15.0* |
| 6 | 625 | | X | X | | | | | 8.1 | 20.5<br>20.0* | 15.7<br>21.0* |
| 7 | 230 | - - - - -No Information- - - - - - | | | | | | | 10.0 | 58.3 | 163.0 |
| 8 | 250 | - - - - -Not Available - - - - - - | | | | | | | 22.0<br>25.0* | 22.7 | 52.0 |
| 9 | 285 | | | | | | | | 3.5 | 8.9 | 71.0 |
| 10 | 300 | | | | | | | | | N/A | N/A |
| 11 | 250 | X | | X | | | | | 7.1 | 9.1 | 10.7 |
| 12 | NSSC 250<br>Paper 145 | | | X | | | | | 3.5 | 17.5 | 18.1 |

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## NEUTRAL SULFITE SEMI-CHEMICAL MILLS (AMMONIA BASE)

| Mill No. | Tons/ Day | Treatment C | L | ASB | AS | SO | SS | CD | Flow G/Ton x1000 | Discharge TSS #/Ton | BOD #/Ton |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 500 | X | | X | | | | X | 8.6 | 6.5 | 18.0 |

## COMBINATION KRAFT AND NSSC MILLS

| Mill No. | Tons/ Day | Treatment C | L | ASB | AS | SO | SS | CD | Flow G/Ton x1000 | Discharge TSS #/Ton | BOD #/Ton |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1320 | | | X | | | | | 19.1 | 4.7 | 2.0 |
| 2 | 1600 | X | | X | | | | | 10.6 | 7.4 | 7.3 |
| 3 | 2100 | X | | X | | | | X | 20.0 | 12.7 | 6.0 |
| 4 | 1955 | X | | | | | | | 7.7 | 10.3<br>10.0* | 13.0<br>12.0* |
| 5 | 666 | X | | | | | | | 10.5 | 25.4<br>35.0* | 33.9<br>26.0 |
| 6 | 1030 | X | | | | | | | 20.3 | 26.8<br>42.0* | 40.0<br>41.0* |
| 7 | 820 | X | | X | | | | | 16.6 | 5.3 | 8.8 |
| 8 | 770 | X | | X | | | | | 8.0 | 1.5 | 3.1 |
| 9 | 1680 | | X | | | X | | | 27.9 | 320.0 | 132.0 |
| 10 | 1464 | X | | X | | | L | X | 25.3 | 5.4 | 9.4 |

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## PAPERBOARD FROM WASTE PAPER

| Mill No. | Tons/ Day | Treatment C | L | ASB | AS | SO | SS | CD | Flow G/Ton x1000 | Discharge TSS #/Ton | BOD #/Ton |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 125 | X | | X | | | L | | 16.0 | 0.34 | 0.4 |
| 2 | 115 | X | | | | | L | | 0.01 | .07 | 0.4 |

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Paperboard from Waste Paper Mills- cont'd.

| Mill No. | Tons/ Day | Treatment | | | | | | | Flow G/Ton x1000 | Discharge | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | C | L | ASB | AS | SO | SS | CD | | TSS #/Ton | BOD #/Ton |
| 3 | 240 | X | | | | | L | | 8.4 | 0.5 | 21.1 |
| 4 | 804 | X | | | X | | C | | 7.6 | 5.1 | 2.7 |
| 5 | 80 | X | | | X | | | | 12.5 | 10.6 | 0.3 |
| 6 | 59.1 | X | | | X | | | | 11.9 | 0.25 | 0.17 |
| 7 | 165 | X | | X | | | L | | 4.6 | 5.6 | 7.4 |
| 8 | 122 | X | | | | | | | 5.7 | 14.2 | 15.3 |
| 9 | 90 | X | | X | | | C | | 10.0 | 4.6 | 3.0 |
| 10 | 275 | X | | X | | | L | | 2.3 | 2.5 | 1.0 |
| 11 | 320 | X | | | X | | | | 8.4 | 6.0 | 1.4 |
| 12 | 275 | - - - - - Not available - - - - - | | | | | | | 14.5 | 31.6 | 14.5 |
| 13 | 250 | | X | | | X | | | 1.2 | 0.7 | 0.1 |
| 14 | 850 | X | | | X | | X | | 3.5 | 0.5 | 0.4 |
| 15 | 150 | X | | | | | | | 0.18 | 0.00 | .003 |
| 16 | 80 | | X | X | | | | | | | |

# Appendix III

## Development of Costs

### Pretreatment Technology

Internal Measures

The internal measures can be summarized as follows:

907 kkg/day (1000 tons/day) unbleached kraft linerboard
mill and 907 kkg/day (1000 tons/day) kraft - NSSC mill
- addition of spill collection provisions for chemicals and fibers
- installation of low volume, high pressure self cleaning showers on all paper machines
- filtering and reuse of press waters

907 kkg/day (1000 tons/day) paperboard from waste paper mill
- land disposal of junk materials
- installation of low volume, high pressure self cleaning showers on paper machines
- filtering and reuse of press water

227 kkg/day (250 tons/day) NSSC - Na mill

- addition of liquor recovery system
- installation of low volume, high pressure self cleaning showers on paper machines
- filtering and reuse of press water

External Treatment

For all case mills the liquid external treatment consists of raw waste screening by bar screens, primary treatment by mechanical clarifiers, foam control, effluent monitoring and automatic sampling and outfall system by diffuser.

The screenings are burned in bark burners in case of the kraft linerboard mill, the kraft - NSSC mill and the NSSC - Na mill. The screenings are sanitary landfilled in case of the paperboard from waste paper mills.

The sludge is dewatered by vacuum filter and sludge press and sanitary landfilled for kraft linerboard and kraft - NSSC mills, while the sludge is dewatered by vacuum filters and sanitary landfilled for the paperboard waste paper mill and the NSSC - Na mill.

## BPCTCA Technology

### Internal Measures

The internal measures to bring the base mills up to BPCTCA technology consist of the additions already made plus the following:

907 kkg/day (1000 tons/day) unbleached kraft linerboard mill and 907 kkg/day (1000 tons/day) kraft - NSSC mill

-evaporator boil-out storage tanks
-pressure screening (hot-stock)
-segregation and reuse of white waters
-collection and reuse of vacuum pump seal waters
-installation of savealls, and
-gland water reduction

907 kkg/day (1000 tons/day) paperboard from waste paper mill, 227 kkg/day (250 tons/day) NSSC - Na base mill and 227 kkg/day (250 tons/day) NSSC - $NH_3$ base mill

-segregation and reuse of white waters
-collection and reuse of vacuum pump seal waters
-installation of savealls, and
-gland water reduction

### External Measures

Screening, primary, and secondary treatment are provided to total mill effluents for all case mills, where the screening is by bar screens and primary sedimentation in mechanical clarifiers as was used when the upgrading was done in the previous upgrading step.

Secondary treatment is provided by nutrient addition, aerated lagoon treatment and biological solids separation in mechanical clarifiers. An emergency spill basin is installed prior to the secondary treatment step.

Foam control, flow monitoring and sampling and outfall system are as used under previous upgrading step.

The solids dewatering and disposal process is the same as the one used in the previous upgrading step.

## BATEA Technology

## Internal Measures

The internal measures to bring the base mills up to BATEA consist of BPCTCA installations plus the following additions:

907 kkg/day (1000 tons/day) unbleached kraft linerboard mill, 907 kkg/day (1000 tons/day) kraft - NSSC mill, 227 kkg/day (250 tons/day) NSSC - Na base mill, and 227 kkg/day (250 tons/day) NSSC - NH3 base mill

-expanded process water reuse

-separation of cooling water and recovery of heat

91 kkg/day (1000 tons/day) paperboard from wastepaper mill

-no additional installations beyond those selected to bring these mills up to BPCTCA.

## External Measures

All mill effluents are screened by bar screens and are subjected to primary solids separation in mechanical clarifiers and secondary treatment by nutrient addition, activated sludge treatment and secondary solids separation in mechanical clarifiers. An emergency spill basin is provided prior to the secondary treatment step.

The 907 kkg/day (1000 tons/day) kraft linerboard mill, and the 907 kkg/day (1000 tons/day) kraft - NSSC mill effluents receive color removal by lime treatment. The 227 kkg/day (250 tons/day) NSSC - sodium base and ammonia base mills have reverse osmosis systems for color removal.

All mill effluents receive further solids reduction by mixed media filtration.

All mill effluents receive foam control treatment, monitoring and automatic sampling prior to entering the receiving waters through diffusers.

Screenings from the linerboard mill and the kraft - NSSC mill effluents are burned in sludge incinerators, and screenings from the NSSC - Na and NSSC - NH3 base mills are burned in existing bark boilers.

Primary sludges and waste activated sludge are thickened in gravity sludge thickeners, and dewatered mechanically by vacuum filters and presses prior to ultimate disposal.

Ultimate sludge disposal for the kraft linerboard mill and the kraft - NSSC mill is by incineration, and for the other mills by sanitary landfilling.

## NSPS Technology

### Internal Measures

Internal measures are not costed because such measures are included in the design of new mills.

### External Measures

All mill effluents are screened, receive primary solids separation in mechanical clarifiers, and secondary treatment by nutrient addition, activated sludge treatment and secondary solids separation by mechanical clarifiers. Emergency spill basins are provided ahead of the secondary treatment step.

All effluents receive foam control, monitoring and automatic sampling prior to outfall by diffusers.

The 907 kkg/day (1000 tons/day) unbleached kraft and kraft - NSSC (cross recovery) mill effluents receive color removal by lime treatment.

Screenings from the kraft linerboard mill, the kraft - NSSC mill, the NSSC - Na and the NSSC - NH3 mills are burned in existing bark burners. The screenings from the other mills are disposed of by sanitary landfilling.

Primary sludge and wasted activated sludge are thickened in gravity thickeners prior to mechanical dewatering by vacuum filters and presses.

Sludges from the kraft linerboard mill and the kraft - NSSC mill are incinerated, while all other sludges are disposed of by sanitary landfilling.

## INTERNAL TREATMENT

The following unit prices have been used for the internal measures:

Power 0.60 ¢/kwh
Heat 3.50 $/$10^9$ cal
Maintenance: 2.5% of capital cost, annually

Costs of heat exchangers, storage tanks, pumps and pipes are estimated according to Chemical Engineering, March 24, 1969, issue and updated to August 1971 price levels.

It should be recognized that costs of internal process modifications may vary greatly from mill to mill, and that cost of internal improvements should be evaluated upon consideration of local conditions.

## Spill and Evaporator Boilout Storage

Chemical spills are collected, pumped to storage and fed into the black liquor evaporator plant. Fiber spills from floor drains are recovered in a save-all and returned to the pulp line.

Investment costs for 907 kkg/day (1000 tons/day) Kraft Mill are:

| | $1000 |
|---|---|
| Overdesign of evaporation plant (installation of one additional effect) | $1150 |
| Chemicals storage tank (260000 gal) | 100 |
| Fiber storage tank (8000 gal) | 5 |
| Saveall | 150 |
| Pumps, pipes, valves | 450 |
| Instrumentation | 100 |
| Total | $2000 |

Operating costs will be zero since value of recovered chemicals and fibers will cover operating expenses. However, value of recovered fibers and chemicals will not cover capital expenses.

## NSSC-Na Copeland Recovery Process

Assumed process parameters and operating conditions of the Copeland installati

| Pulping Process | | NSSC |
|---|---|---|
| Pulp Production, ADTPD | 200 | |
| Yield, % | 75 | |
| Washing efficiency, % | 90 | |
| Chemical Requirements, LB/ton | | |
| $Na_2CO_3$ | 440 | |
| Sulfur | 95 | |
| Weak liquor concentration, % solids | 10 | |
| Heat value on weak red liquor BTU/lb | 5600 | |
| Waste liquor feed (1) 263 GPM | 70.4 | t/hour |
| Conc. liquor product (2) 91 GPM | 27.3 | t/hour |
| Evaporation capacity 1 $H_2O$/hr | 50 | |
| Steam requirements, TGPS/hr (3) | 20 | |
| Air blower horsepower, HP | | |
| Connected | 900 | |
| Operating | 675 | |
| Process power requirements, kw | | |
| Connected | 350 | |
| Operating | 275 | |

(1) Sp. Gr.: 1.07, 10% solids
(2) Sp. Gr.: 1.20, 35% solids
(3) Triple-effect evaporation

Operational utilities required for application of Container - Copeland Process:

| | |
|---|---|
| Low pressure steam, ton/hr | 20 |
| High pressure steam, ton/hr | 5 |
| Electric Power, kw | 780 |

## Operating Cost

| | |
|---|---|
| Steam 2.04 DOL/T steam, 8400 hours/year | 429000 $/yr |
| Electric power (0.6 c/kwh, 8400 hours/year) | 39000 $/yr |
| TOTAL | 468000 |

## Investment Cost Estimate

| | $1000 |
|---|---|
| Evaporation plan (triple effect) | 480 |
| Liquor burning and chemical recovery | 1,100 |
| Feedwater treatment | 100 |
| Buildings (27 US DOL/cu ft) | 280 |
| Planning, Design, Etc. | 10 |
| TOTAL | 2,060 |

(The cost does not include compressor station, electrical supply station, outside piping, and turbines.)

## Land Disposal of Junk Materials

The cost has been calculated on the basis of an external transportation contract, and no capital cost has been assumed, The cost of transportation has been estimated to 20 cent/ton-mile, and cost of disposal to $1.5/ton. Transportation distance has been taken to 10 miles. Amounts of junk materials are as shown in flow diagrams, or:

For the paperboard from waste paper mill:
3 ton junk materials a day
3 ton/day (20 cent x 10 miles + 150 cent/ton) =
1050 cent/d

## Paper Machine Controls

High pressure self cleaning, low volume showers for paper machine and press water filter for removing felt hairs.

The following paper machine widths have been assumed:

| | |
|---|---|
| -1000 tons/day liner board machine | 28 feet |
| -750 tons/day liner board machine | 21 feet |
| -250 tons/day corrugated board machine | 14 feet |
| -100 tons/day wastepaper board machine | 14 feet |

Capital cost has been calculated to 14 feet width and then converted to other widths by using a liner factor.

Cost for each unit:

| | | |
|---|---|---|
| -4 shower pipes | 14 feet | 12,000 |
| -2 pumps (10 kw) | | 2,000 |
| -1 smith screens | | 1,000 |
| -4 water saveall pans | | 3,000 |
| -2 hair screens, smith | | 1,000 |
| -tank, piping, hoses | | 4,000 |
| -spares | | 1,000 |
| -design, instrumentation, electricity, installation, etc. | | 11,000 |
| TOTAL | | $35,000 |

The cost of this item for a 14 foot corrugated board machine:

| | |
|---|---|
| Wire part | 35,000 |
| Press part | 35,000 |
| Cylinder forms | 35,000 |
| | 105,000 |

For kraft liner machines:

| | 1000 tons/day | 750 tons/day |
|---|---|---|
| Wire part | 55,000 | 45,000 |
| Press part | 55,000 | 45,000 |
| | 110,000 | 90,000 |

## Spill Control

By spills it is are meant releases of wood fibers and/or process additions to those which are "normal" for the process. The release of the "normal" pollutant load for a process depends upon the process design and equipment used, and is therefore reasonably well defined or deterministic in nature. The spills are caused by "accidents" or mechanical failures in the production facilities and are as such probabilistic in nature.

The accidental spills are in general of short duration and usually have a fiber and/or concentration of chemical substances which are several times those of the normal mill effluents (1). Another undesirable property associated with accidental spills is that they might not be intercepted by the waste water collection system that finds its way into the storm sewers and therefore bypasses all treatment waters.

The main sources of accidental losses are:

a) leaks and overflows from storage tanks
b) leaks and spills resulting from repairs, system changes and mistakes in departments handling strong liquor, and
c) overflows from screens and filters in departments handling fiber

Controls of spills can be done by connecting overflow lines to holding tanks equipped with pumps, a procedure which returns chemicals to storage or to the recovery system, and fibers to the stock chest.

Cost of spill control is based on systems shown schematically in Figure 1, Appendix III.

Costs of spill controls are lump sums as shown in the cost summary. These costs include construction costs and mechanical and electrical equipment as shown in Figure 1, Appendix III.

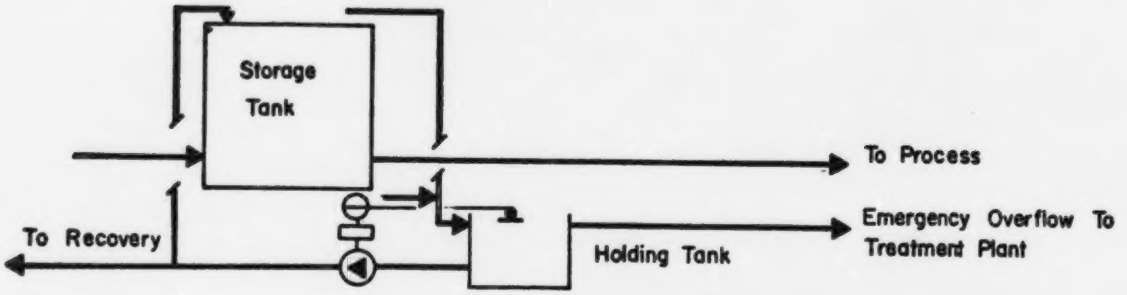
## Large Spills

Large accidental losses caused by mechanical failures can be prevented by an effective control system, e.g., conductivity measurements in the waste water lines. As these losses might render the effluent unsuitable for treatment, an emergency spill basin is constructed to intercept these wastes. The spill basin content is pumped back to the treatment process at a rate which does not "upset" the treatment process.

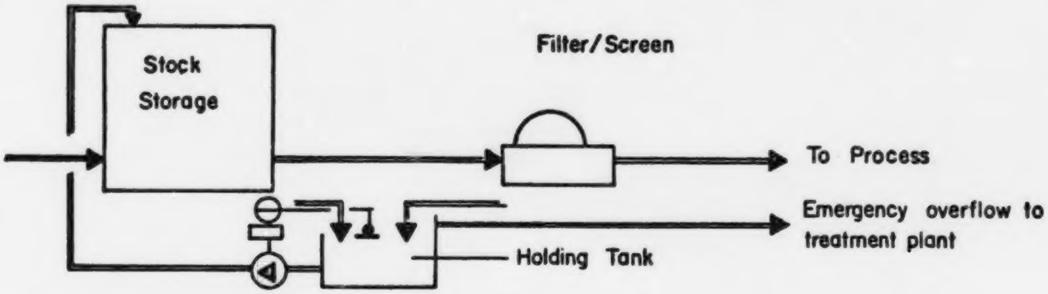
Construction cost of the spill basin is based on a system which is shown schematically in Figure 2, Appendix III.

Design Criteria for Spill Basin:

Volume: 12 hours of average flow
Pump Capacity: Basin volume returned to treatment process in 12 hours at 30 feet head.
Basin: Earthen construction with 12 foot depth


Storage Tank
To Process
Emergency Overflow To Treatment Plant
To Recovery
Holding Tank

a) Control Of Chemical Spills And Losses


Stock Storage
Filter/Screen
To Process
Emergency overflow to treatment plant
Holding Tank

b) Control Of Fiber Containing Spills

Figure 1 Spill Control Installations

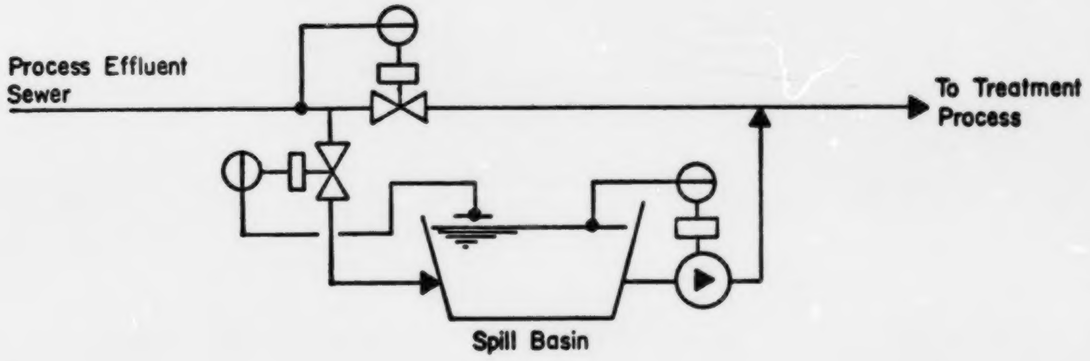

Process Effluent Sewer
To Treatment Process
Spill Basin

Figure 2 Spill Basin and Controls

## Sewers

### Plant Sewers

Plant sewers are defined as the gravity flow type conveyance facilities within the boundaries of the treatment plant. These may be both closed conduits and open channels. The capital costs of these items are included under the respective treatment plant components.

Annual operation and maintenance costs of in-plant sewers have been taken at a flat 0.50% of the estimated construction cost with no differentiation between materials of construction, except as reflected in the construction cost.

### Interceptor Sewers

Interceptor sewers are defined as the conveyance facilities which connect the mill to the treatment plant and the treatment plant to the outfall system. Thus, they may vary from being insignificant in a situation where land is available adjacent to the mill, whereas they may amount to a large percentage of the treatment plant cost where long interceptor sewers are required. For this reason no interceptor sewers are included in this study.

### Submarine Outfalls

The costs of these facilities are based on moderately severe oceanographic conditions. Costs include pipe, excavation, laying and jointing, backfill where necessary, provision of protection against scour, a straight diffuser section at outlet and with multiple outlets for efficient initial dilution, testing, and cleanup.

Annual operation and maintenance costs of outfall systems have been taken at a flat 0.50% of the estimated construction cost.

## Land Requirements and Costs

### Land Requirements

A site suitable for an effluent treatment facility should have the following properties:

- should be within a reasonable distance from the production facilities so that long and expensive interceptor sewers are eliminated.
- should be far enough from the production facilities so that their expansion possibilities are not hampered.

- should be at a suitable elevation relative to the production facilities so that pumping costs are minimized, and ideally allow for gravity flow through all treatment units.
- should allow for orderly future treatment plant expansion on land which can be purchased at a reasonable price and with adequate soil properties.

The two major factors affecting the area requirements for external waste water treatment are the type of secondary treatment and the type of sludge disposal. The approximate land requirements for the most commonly used secondary treatment methods used in the pulp and paper industry are shown below.

Land Requirement for different secondary treatment methods

| Treatment Method | Land Requirements - Acre/MGD |
|---|---|
| Natural Stabilization | 40.0 |
| Aerated Stabilization | 2.0 |
| Activated Sludge | 0.04 |

Land required for ultimate solids disposal depends on the sludge quantities generated, moisture content, ash content and method of placement.

Land requirement for different ultimate sludge disposal methods (Disposed effluent at 12 feet depth)

| Disposal Condition | Land Requirements sq ft / ton dry solids |
|---|---|
| Thickened clarifier underflow, 5% solids | 53.0 |
| Centrifuge cake, 20% solids | 16.5 |
| Pressed cake, 35% solids | 11.6 |
| Incineration, 3% ash | 0.15 |
| Incineration, 12% ash | 0.60 |

Land Costs

The value of land is often difficult to establish. Depending upon land availability and alternate land use, the land cost might vary from $1.00 per square foot or more down to only a few cents per square foot. For the purpose of this study a land cost selected was $4,000 per acre.

## EXTERNAL TREATMENT

## Pretreatment

Pretreatment consists of screening only for all alternatives considered in this report.

Total effluents from all mills considered in this study usually lose coarse material in the form of chips, bark, wet strength paper, etc., in quantities that require screening to avoid plugging of sludge lines and escape of floating objects over overflow weirs.

Although vibrating screens have proven satisfactory when the flows are small (2-4 MGD), traveling screens with one inch openings have been recommended (2) and are used for all mills included in this study.

Design Criteria:
Type: Travelling bar screens
Design Flow: Average daily
Bar Spacing: 1 inch
Capital Cost in $1,000 =
11 + .27 x Q + 7.64 X Q**.625
where: Q = average daily flow in MGD
(cost information from numerous individual installations was also considered in all cases).

Capital cost and annual operation and maintenance costs for raw waste screening are shown graphically in Figure 3, Appendix III.

## Primary Treatment

Primary treatment is most economically done when all fibers containing wastes are mixed before treatment. Besides the fact that large units give lesser treatment costs than a series of smaller units, mixed effluents generally also have improved settling characteristics, thus decreasing the total treatment unit requirements. Internal fiber recovery is assumed done to the maximum economic justifiable degree, so that no external fiber recovery for reuse is considered in the treatment process design.

Three unit operations for suspended solids separation have been considered. These are:

a) settling ponds
b) mechanical clarifiers
c) dissolved air flotation

Settling Ponds - Design Criteria:
Construction: earthen construction, concrete inlet and outlet structures
Detention time: 24 hours

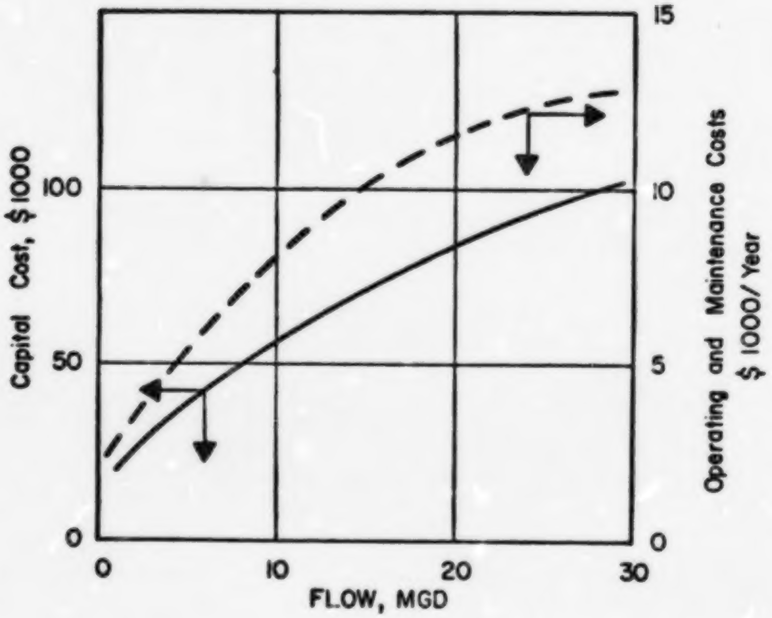


Figure 3 Capital And Operation Cost For Raw Waste Screening

Water depth: 12 feet
Sludge removal: manual
Cost Functions:
Capital cost in $1000 = 27.3 x**0.75
where: V = pond volume in million gallons

This construction cost function is based on work bin Reference (3). The construction cost, which includes plant sewers, and all diversion - inflow-, and outflow- structures, but excludes land costs, is shown graphically in Figure 4, Appendix III. The function is "verified" by plotting data from the field survey phase on the same figure.

Operation Costs:

The operation cost of sedimentation ponds consists mainly of sludge dredging and disposal which was estimated to cost $6.50 per ton of dry solids removed.

Annual maintenance was estimated to be 1% of capital cost.

### Primary Clarifiers

Construction: Circular heavy duty plow type rotary sludge scraper, scum collection and removal facilities.

Overflow rate: 700 gpd/ft**2 (4) Widewater depth: 15 feet

Capital cost in $1000 (3) =
62x((1.5 - 0.001Qx1000./OR)**0.60

where: Q = flow in MGD
OR = overflow rate in gpd/ft**2

The construction costs include all mechanical and electrical equipment, instrumentation, installation, and sludge pumps and plant sewers. Land costs are not included. This cost of function is shown graphically in Figure 5, Appendix III and includes data from the field survey phase of the project.

## Secondary Treatment

BOD removal, i.e. secondary treatment, in the pulp and paper industry is usually done by a biological process. However, no single design of any biological treatment process is applicable to all pulp and paper mill effluents. Four different biological units in various combinations have been considered in this report: a) biological filters, b) natural oxidation ponds, c) aerated lagoons (or aerated stabilization basins), and d) activated sludge treatment units.

### Biological Filters

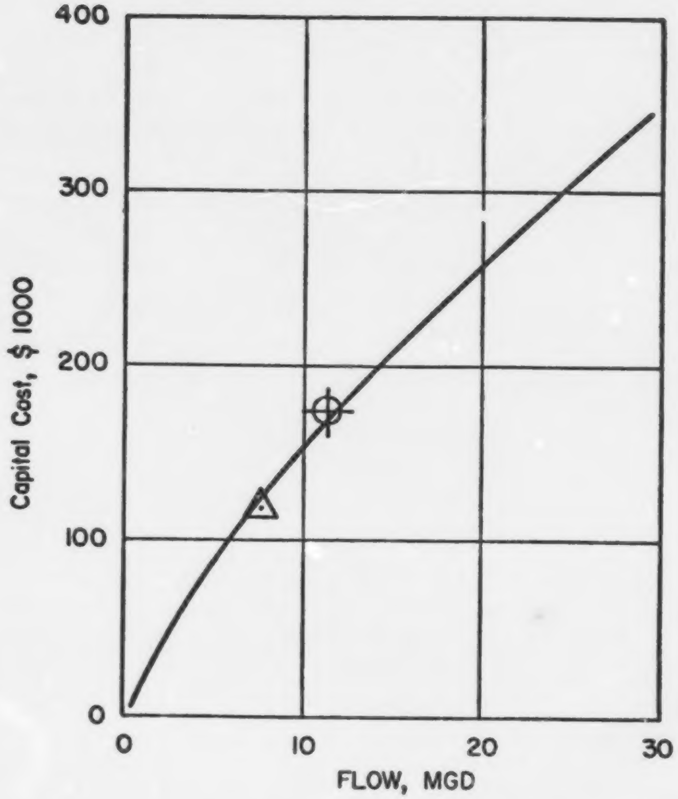


Figure 4 Construction Cost of Earthen Settling Ponds

△
○ Project Cost Files

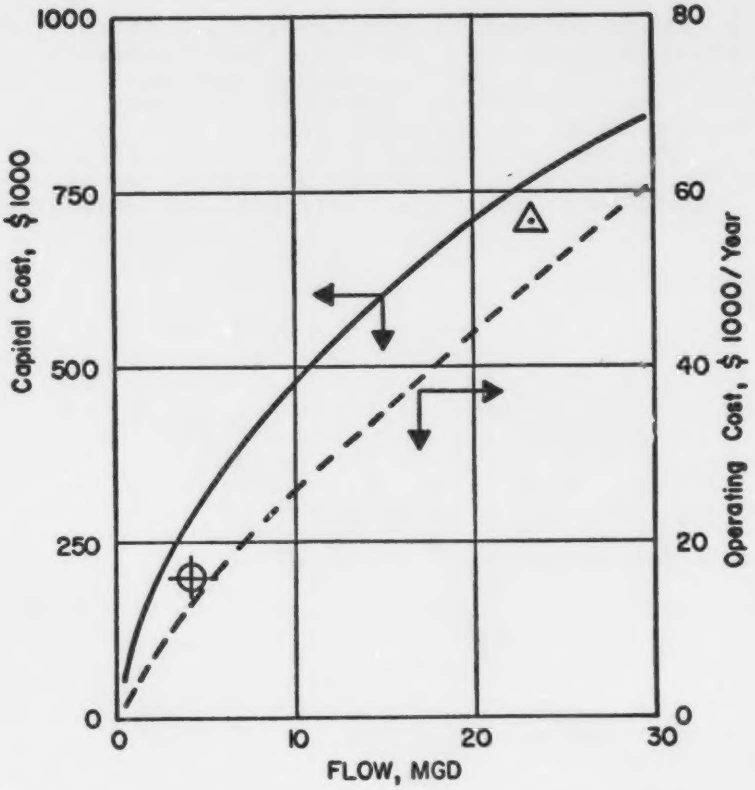


Figure 5 Capital and Operating Costs For Mechical Clarifiers

Capital Cost Case Studies:

△ Project Cost Files
○

In spite of a serious attempt to use biological filters, they have not found widespread use in the pulp and paper industry. According to Reference (6), this fact is due to plugging problems and $BOD_5$ loadings which prohibit high efficiency removals. A summary (6) on tickling filter performance shows BOD removals, ranging from 25 to 52%. With these removal degrees it can be concluded that trickling filters can only be used successfully as a roughing device prior to additional treatment. Trickling filters are, therefore, not considered further in this study.

Natural Oxidation Ponds

From a cost standpoint, this treatment method can only be considered when large areas of "inexpensive" land are available. Another factor limiting their use in the pulp and paper industry is that the effluent colors are usually higher than those of sanitary wastes and, consequently, the growth of the algae population might be prohibited or reduced, resulting in lesser oxygen quantities available for the biochemical process. However, for mills located in the South, where climatic conditions are appropriate for photosynthetic activity throughout the year and large land areas are often available, this method is reasonably effective.

Decomposition products from the biological mass will accumulate on the sludge bottom and may have to be removed periodically.

Design criteria:
Construction: earthen, unlined, concrete inlet and outlet structures
Loading rate: 50 lb BOD/acre/day (7)
Liquid depth: 5 feet (7)
BOD removal: 85%
Cost functions: Capital cost in $1000 (3) = 62800 x A**0.74
where A = pond area in acres

The cost function includes all material and labor required for all earth moving, bank stabilization, concrete work and plant sewers. Cost of land is not included.

Operation cost was considered independent of pond size and estimated to be $6000 annually.

Since the rate of metabolism is low and the detention time is long, it is assumed that the biomass will lyse and no nutrient addition is assumed necessary.

Maintenance cost is estimated to be 0.75% of the capital cost annually.

Aerated Lagoons

The aerated lagoon system used for the costing basis consists of two aerated cells in series as shown in Figure 6, Appendix III. This system

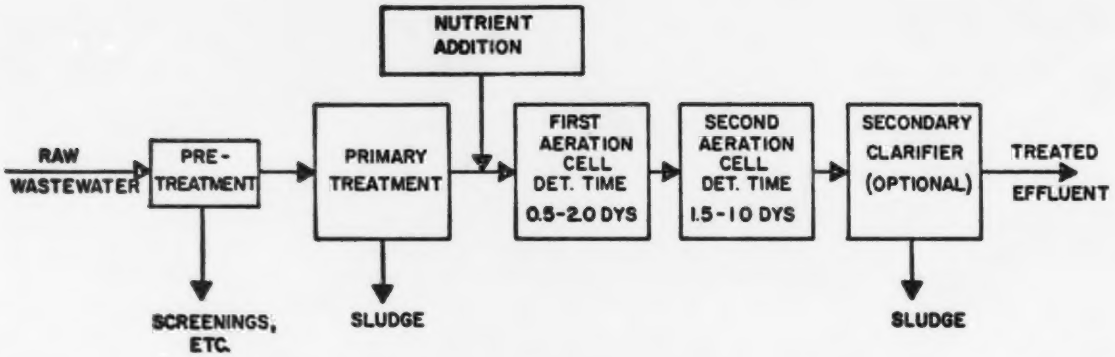

NUTRIENT ADDITION
RAW WASTEWATER
PRE-TREATMENT
PRIMARY TREATMENT
FIRST AERATION CELL DET. TIME 0.5-2.0 DYS
SECOND AERATION CELL DET. TIME 1.5-10 DYS
SECONDARY CLARIFIER (OPTIONAL)
TREATED EFFLUENT
SCREENINGS, ETC.
SLUDGE
SLUDGE

Figure 6 Aerated Lagoon Treatment Plant

was chosen because it usually gives better overall performance at lower land requirements than the conventional single cell does. The aeration system consists of mechanical surface turbine aerators. Minimum power levels are assigned to ensure adequate mixing and oxygen distribution.

Nutrients are added in proportions to biological mass production and solids wasted in the effluent. It is assumed that the biomass will lyse and release nutrients to a large degree in the second cell, so that nutrient addition is required only in the first cell. Nutrients have been added in quantities as determined by Reference #8 in that 4 pounds of nitrogen and 0.6 pounds of phosphorus should be provided per 100 pounds of BOD removed. Nutrient content in the influents are included in these values.

Design Criteria: Aeration Cells

Construction: earthen construction, stabilized banks, lined for seepage prevention, concrete inlet and outlet structures, two cells in series.

Liquid depth: 15 feet

Nutrient addition: 4 pounds of nitrogen and 0.6 pounds of phosphorus per every 100 pounds of BOD removed. Influent nutrients are subtracted from these values.

Aerators:

Type: mechanical surface turbine aerators
Minimum power levels: 20 HP/MG in first cell (9)
6 HP/MG in second cell (9)

Secondary clarifiers:

Construction: Circular, concrete tanks, plow type rotary sludge scraper
Overflow rate: 600 gpd/ft**2
Sidewater depth: 15 feet

Cost functions: Capital Costs in $1000:
Aeration cells (10) = 62.8 x A**0.74
where A = total cell area in acres

Aerators (10) = 1.13 x HP**0.80
where HP = total horsepower installation

Secondary clarifiers (3) = 62.*((1.5-0.001Q)Q x 1000/QR)**0.60

where Q = flow in MGD
QR = overflow rate in gpd/ft**2

Operating and Maintenance Costs:

Aeration Cells:

Annual aeration cell maintenance costs were taken to be 1.0 percent of capital costs (10).

Nutrient costs were calculated on the basis of $250 per ton of nitrogen and $380 per ton of phosphorus.

Sludge removal cost was based on the assumption that 0.2 ton of sludge settles to the aeration basin bottom per ton of BOD removed and that the unit price of sludge removal is $7.50/ton. This sludge accumulation rate is representative of existing field installations for aerated lagoons.

Operation cost estimates were based on work in Reference (11):
Annual cost: 18.5 x Q**0.25
where Q = average daily flow in MGD

Aerators:

Annual maintenance costs for the aerators were taken to be 10% of installed aerator cost (10). Power cost used 1.1 cents/kwh.

Secondary Clarifiers:

Annual operation and maintenance costs were obtained from work in Reference (5) and are:

1360 Q + 3537 x Q**0.5
Q = average daily flow in MGD

Activated Sludge

All costs for activated sludge treatment considered in this study are for completely mixed systems, and with biological reaction and oxygen utilization rates representative of the particular effluents undergoing treatment. The completely mixed system was selected because of its ability to handle surges of organic loads and slugs of toxicants. The activated sludge plant used for the costing basis is shown in Figure 7, Appendix III.

Design Criteria:

Aeration Tank:

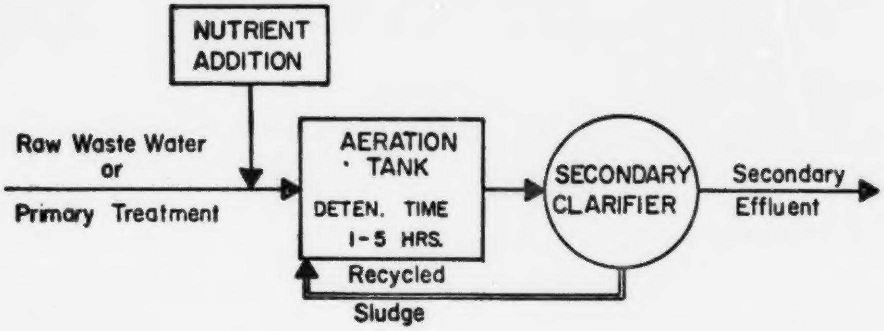

NUTRIENT ADDITION
Raw Waste Water
or
Primary Treatment
AERATION TANK
DETEN. TIME
1-5 HRS.
SECONDARY CLARIFIER
Secondary
Effluent
Recycled
Sludge

Figure 7 Completely Mixed Activated Sludge System

Construction: reinforced concrete with pier mounted surface
aerators.

Liquid Depth: 15 feet

Nutrient addition: 4 pounds of nitrogen and 0.6 pounds of
phosphorous per every 100 pounds of BOD
removed. Influent nutrients are subtracted
from these values.

Aerators: Type: mechanical surface aerators

Secondary Clarifiers:
Construction: circular concrete tanks with rotary suction
type sludge collector
Sidewater depth: 15 feet

Cost Functions: Capital costs in $1000
Aeration tank (3) = 225 x V**0.71
where V = tank volume in million gallons

Aerators (3) = 1.75 x HP**0.81
where HP = total horsepower installed

Secondary clarifiers (3) = 62.*(1.5-0.002Q)Q*1000.OR)**0.60
where Q = flow in MGD, including recycle
overflow rate in gpd/ft**2

Sludge recycle pumps (3) = 5.36 + 1.66 x Q
where Q = average daily flow in MG

Operation and Maintenance Costs

Cost of operation and maintenance of activated sludge system has been calculated using a cost function developed in Reference 5. This cost function includes operation and maintenance of aeration basins, aerators, final sedimentation tanks and sludge return pumps:

Operation cost (¢/1000 gal) = R x (3.40 + 4.95/v**0.5
where V= basin volume in million gallons
R=retention time in days

The breakdown between operation and maintenance is 60% and 40%, respectively (10).

Power cost is calculated from the net horsepower requirements at 1.1¢/kwh.

Nutrient cost are calculated on the basis of $250 per ton of sludge and $380 per ton of phosphorus.

## Color Removal

Basis: "minimum lime" process
Costs include addition of lime kiln capacity, mixing eqmt., lime clarifier w/associated lime sludge thickening and handling, necessary pumps, piping, instrumentation and auxiliaries.

### 1000 T/D Unbleached Kraft Mill

capital: $1,800,000 + 35% engr. legal and contingency = $2,430,000
operating (maint., spares, power, make-up chemicals, labor, insurance and taxes) = $ 297,500/yr
add: 15% of 2,430,000 interest + depr. = 364,500
total annual cost = $ 662,000
less: energy cost at 40% of 297,500 = 120,000
annual cost less energy = $ 542,000

$\frac{\$542,000}{1000 \times 350}$ = $1.50/ton less energy
T/D Days/Yr

$\frac{120,000}{1000 \times 350}$ = .35/ton energy
1.85/ton total

### 1000 T/D Cross-Recovery NSSC-Kraft Mill

capital: $1,500,000 + 35% = $2,025,000
operating (same basis as above) = $ 280,000/yr
add: 15% of 2,025,000 depr+int. = 304,000
total annual cost = $ 584,000
less: energy cost at 40% of 280,000 = 112,000
$ 472,000

$\frac{\$472,000}{1000 \times 350}$ = $1.35/ton less energy

112,000 = 0.32/ton energy

1000 x 350          $1.67/ton total

## Sodium Base NSSC-250 T/D

200 T/D mill (i.e. 250 T/D w/50 T/D wastepaper)
1  Capital cost $250,000 turnkey, 100GPM = 150,000 gal/day

**Annual Costs**

depr. + interest at 15% of $250,000 = $37,500
operating cost incl. energy

$$\frac{150{,}000\ \text{gal}}{\text{day}} \times \frac{350\ \text{days}}{\text{yr}} \times \frac{\$0.95\ 2}{1000\ \text{gal}} = \$50{,}000$$

increase by 40% to reflect higher unit costs in 150,000 gal/day unit of w/500,000 gal/day in 2.

$$\$50{,}000 \times 1.40 = \underline{\quad 70{,}000}$$

$$\text{total annual cost} = \$107{,}500$$

less: elec. power costs

$$\text{HP} = \frac{(100\text{gpm})}{1714}\ \frac{(600\text{psi})}{(.60)} = 60\ \text{HP for R.O}$$

$$+ \text{ est. for transfer pumps} = \underline{20\ \text{HP}}$$

$$\text{total est. HP} = 80\ \text{HP} = 60\text{kw}$$

$$\frac{60\text{kw}\ \$.011}{\text{kw-hr}} \times \frac{24\ \text{hr}}{\text{day}} \times \frac{350\ \text{days}}{\text{yr}} = \frac{\text{power cost}=}{5{,}500}$$

total annual cost
less power = $\underline{\$102{,}000}$

**Cost Per Ton**

$$\frac{\$102{,}000}{200\text{T/D} \times 350\ \text{days/yr}} = \$1.50 \text{ per ton (not incl. power)}$$

$$\frac{\$\ \ 5{,}500}{200 \times 350} = \underline{0.79} \text{ per ton (power)}$$

$2.29 total cost per ton

## Ammonia Base - 200T/D+50T/D Waste Paper = 250T/D

No data available.
Assume same as sodium base.

## Mixed Media (Multi-Media) Filtration for Suspended Solids Removal

### 1000 T/D Unbleached Kraft Mill

capital: $240,000 + 35% = $325,000
operating $123,000
add: 15% of 325,000 for int.+depr. = 18,500
total annual cost = $141,500
less: 35% of 123,000 for energy = 43,000
annual cost less energy = $ 98,500

$98,500
1000x350 = $0.28/ton less energy
T/D days/yr

43,000
1000x350 = 0.12/ton
$ .40/ton total

### 1000 T/D Cross-Recovery Mill

capital: $210,000 + 35% = $284,000
operating $100,000
add: 15% of 284,000 (int.+depr.) = 43,000
total annual cost = $143,000
less: energy at 35% of 100,000 = 35,000
annual cost less energy = $108,000

$108,000
1000x350 = $.31/ton less energy

35,000
1000x350 = .10/ton energy
$.41/ton total

### 250 T/D NSSC-Sodium Mill

capital: $100,000 + 35% = $135,000
operating 37,000
add: 15% of 135,000 (int+depr.) = 20,000
total annual cost = $ 57,000
less: energy at 35% of 37,000 = 13,000
annual cost less energy = $ 44,000

44,000
250x350 = $.50/ton less energy

13,000
250x350 = .15/ton energy
$.65/ton total

## 250 T/D NSSC - Ammonia Mill

capital: $120,000 + 35% = $162,000
operating 73,500
add: 15% of 162,000 = 24,000
total annual cost = $ 97,500
less: energy at 35% of 73,000 = 26,000
annual cost less energy = $ 71,500

$\frac{\$71,500}{250\times350}$ = $.82/ton less energy

$\frac{26,000}{250\times350}$ = .30/ton energy
$1.10/ton total

## Paperboard from Waste Paper 100/TD

capital: $75,000 + 35% = $101,000
operating $ 12,300
add: 15% of 101,000 = 15,000
total annual cost = $ 27,300
less: energy at 35% of 12,300 = 4,300
$ 23,000

$\frac{23,000}{100\times300}$ = $0.76/ton less energy

$\frac{4,300}{100\times300}$ = 0.14/ton energy
$0.90/ton total

## SLUDGE DEWATERING

The sludges drawn from the primary and secondary clarifiers require dewatering prior to final disposal. A large number of unit operations are available for this purpose, from which the specific selection depends upon local conditions like sludge characteristics, proportion of primary and secondary sludges, distance to ultimate disposal site, and ultimate disposal considerations.

The units operations considered in this study are sludge settlings ponds, gravity thickeners, vacuum filters centrifuges and sludge presses. The selected sludge dewatering process might consist of one or more sludge dewatering unit operations.

The dewatered sludge solids are usually disposed of either by landfilling or incineration, according to local conditions and the level of technology required. Sludge disposal by landfilling might give very satisfactory solutions provided a suitable site can be found within a reasonable distance from the mill.

Possible harmful effects from landfilling are groundwater pollution by leaching of chemical constituents or decomposition products and erosion by precipitation. Thus, both soil conditions and climate must be suitable to make sludge disposal by landfilling successful, or the required site work might result in a very expensive solution.

Provided air pollution requirements are met, sludge incineration is, from an environmental point of view, a very satisfactory solution, since only inert ashes need to be disposed of. Although the solution is usually quite expensive, especially for small installations, lack of other solutions might make it the only alternative.

Cost of sludge dewatering and disposal commonly accounts for 30-50% of the total treatment cost.

Cost Functions:

Sludge dewatering ponds: Capital cost in $1000 (3) = 125 x V**0.70
where V = volume in MG

The operation cost of sludge ponds consists mainly of sludge dredging and disposal which was estimated to cost $6.50 per ton of dry solids removed.

Annual maintenance cost was estimated to be 1% of capital cost.
Gravity Thickeners: capital cost in $1000 (3)
= (SA)(34.+16.5/exp (SA/13.3)
where SA = surface area in thousands of square feet

Annual operation and maintenance costs of gravity sludge thickeners were estimated to 8% of the capital cost.

Vacuum Filters: capital costs in $1000 (12) = 4.70 x A**.58
where A = filter area in square feet

Operating and maintenance cost for vacuum filtration was based on the following (3):

Labor: 0.5 man-hours per filter hour @ $5.25 per hour
Power cost: 0.15 HP per square foot of filter @1.10 ¢/kwh
Chemicals: $10.00 per dry ton for waste activated sludge, and
$4.00 per dry ton for primary sludges
Maintenance: 5% of capital cost, annually
Centrifuges: capital costs $1000 (12) = 15.65 * (HP)**0.4
where HP = total installed horsepower of the centrifuge.

Operation and maintenance costs have been calculated as follows:

Labor: 0.25 man-hours per hour of centrifuge operation @5.25 per hour (3).

Power cost: 1.10 ¢/kwh
Chemicals: None required for primary sludges increasing linearly
with the fraction of secondary sludges to 8 pounds of
polymer per dry ton of solids @1.25 per pound of polymer.
Maintenance: 10% of capital cost, annually.

Sludge Presses: capital cost in $1000 = 5.75 x (S/F)**0.95
where S = dry weight of sludge, ton/day
F = press load, as a fraction of nominal load

Operation Cost:
Labor: 0.25 hours per hour of press operation @$5.25 per hour
of press operation.
Power: 1.10¢/kwh
Maintenance: 10% of operation cost, annually.

Landfilling: Transport cost: 20¢/ton mile
Transport distance: 10 miles

Incineration: capital cost $1000 (3) = (S/9.6)(170 + 735 x S**0.61)

where S = total solids in tons/day
Incineration: capital cost $1000 (3) = (S/9.6)(170 + 735 x S**0.61)
where S = total solids in tons/day

Operation cost in $1000/yr (3)
(0.001 + 0.004 SE/P)S + S**0.85 x 0.001
where SE = secondary sludge in lbs/day
P = primary sludge in lb/day
S = total pounds of sludge/day.

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# APPENDIX IV

## Exhibit 1

## PRELIMINARY MILL SURVEY FORMAT

Information to be determined prior to mill survey.

1. PRE-VISIT INFORMATION - Obtain information describing the plant prior to the reconnaissance survey. This could include magazine articles describing the facilities, data or drawings furnished by the mill, NPDES data, or any other pertinent information available. This will enable us to get familiar with the mill before we meet with the mill personnel.

2. EVALUATION OF EXISTING DATA - Check the availability of existing data that the mill will make available for our inspection.

Included in this should be any drawings of the inplant or external treatment facilities such as:

- a. Layouts and sewer locations
- b. Flow diagrams of treatment facilities
- c. Flow diagrams of mill process areas
- d. Water balance
- e. Material balances

3. INITIAL MEETING - Establish what procedures will be required of us during the sampling survey. For example, are there any areas of the mill off limits or will the mill want someone with us at all times?

What safety requirements must we follow? Do we need safety shoes, life preservers, hard hats, respirators, etc.? Can the mill supply these?

4. INSPECTION OF MILL - In inspecting the various process areas of the mill, we should identify the following:

- a. Location of individual discharges to the process sewers.
- b. Relative quality and type of individual discharges, i.e., clean, cooling water, contaminated, etc.
- c. Types of sewers, i.e., open, closed, and direction of flow.
- d. Location of existing flow measurement and sampling points and type of equipment in use.
- e. Tentative locations of additional sampling and gauging points.

Where possible, an estimation of the average flow and possible peak conditions will be indicated. Upstream conditions and sewer characteristics will be inspected to ascertain that no flooding or other problems will be encountered during measurement.

f. Methods and procedures in use to prevent or intercept strong spills.

g. Relative amount of process water reuse and adequacy of existing information such as flow diagrams to explain and document the extent, methods, and equipment required for reuse.

5. INSPECTION OF EFFLUENT TREATMENT FACILITIES - In addition to location of existing flow measurement and sampling points we should evaluate the need for additional points and any special equipment needed. Sampling points should be available at the following locations:

a. Primary influent
b. Primary effluent
c. Primary sludge
d. Secondary effluent
e. Secondary sludge (if any)
f. Chemical feed systems
g. Sludge disposal
h. Additional treatment facilities

6. LABORATORY FACILITIES - A complete check of the procedures used by the mill in running its chemical and biological tests should be made by the plant chemist or other responsible party.

Determine whether the mill will allow us to use its lab and/or personnel during the survey. If the mill will allow us to use its facilities, a complete list of equipment available should be made and a list of supplies needed to perform the various tests.

If we can not use the mill's lab, we must determine where we intend to have the samples tested and make the appropriate arrangements.

7. REVIEW INFORMATION AVAILABLE ON FRESH WATER USED AND WHERE USED -

a. Process
b. Sanitary
c. Cooling water
d. Other

Review records showing quantity and quality of fresh water and flow measurement device used.

8. REVIEW INFORMATION AVAILABLE ON THE WASTE WATER DISCHARGE FROM THE POWER PLANT -

a. Determine water treatment facilities employed
b. Facilities used on water discharge
c. Frequency of waste discharges
d. Quality of discharge

9. COST INFORMATION - Determine or have the mill get for us (if they will) any information on the cost of the internal and external treatment facilities. This should include both capital and operating cost for the facilities, preferably for a number of years. The method used by the mill to finance the facilities and the number of years used to write the expense off would be useful.

If possible the cost data should be gotten by area such as internal treatment, primary, secondary, etc. Operating costs should include labor, maintenance, chemicals, utilities, hauling, supplies, and any other costs available from the mill.

10. TIME CONSIDERATIONS - Obtain any available information on the following:

a. Time required to design the facility including the preliminary study and final design.

b. Time to construct the facility.

c. Was construction bid after completion of engineering or done turn-key?

d. What were delivery times for major pieces of equipment -- both internal and external?

e. What delays were encountered in getting approval by the various regulatory agencies?

Determine the availability of any schedules, CPM or Pert charts for the engineering or construction.

Exhibit 2

## Verification Program
## DETAILED INSTRUCTIONS FOR FIELD SURVEY TEAMS

### A. Data Collection

The enclosed material is prepared for the guidance of field sampling and verification crews following the preliminary Mill Reconnaissance Survey.

It is expected that these verification studies will follow along similar lines at all field survey sites, therefore, it is intended that these procedures be followed as closely as possible in order to provide uniformity to the verification program. Where mill conditions are unique, adjustments in program operation may be necessary. If such conditions are found, a justification for the adjustment in method should be prepared, explaining the reasons for the deviations.

The material that follows is pertinent to a specific plant in that it identifies specific sampling locations there. It is expected that other plant sampling locations will be identified in similar fashion and the sampling and analytical emphasis will be placed on those locations that will have the greatest influence in the verification process.

In conjunction with the verification program it is expected that each plant will have in its files records of its wastewater control operations, including daily analyses of the pertinent parameters, such as BOD, SS VSS, pH, flows, production information, etc. Such data as is available should be obtained for a period of at least 13 months (overlap to account for end of year shutdown and startup) including not only daily summary information but the laboratory bench sheets wherever possible. Also, during the field visit every opportunity should be taken to arrange for split samples between the plant lab and the field operation as well as to exchange analytical results on locations that are being sampled and analysed separately. These data will be most valuable in the verification process to establish laboratory bias, if any, of the results reported by the plant in question.

We have purposely selected the hourly grab sample method of sample and composite preparation of the important waste stream components in order to circumvent any errors that may be due to design or faulty operation of any automatic samplers or other sample collection devices. In reference to sampling of process streams within the plant it is of utmost importance that every effort be made to obtain samples from the following process wastewaters in the pulp mill and paper mill areas:

Pulp Mill

wood handling and barking
digester and washings
causticizing
recovery

Paper Mill

wet end
dry end - with and without coating applications.

Integrated sampling programs are preferred, as outlined for the major wastewater and treatment units; however, random grab samples will be acceptable if the sampling locations are not amenable to a more precise technique. In any case, every effort should be made to accommodate the sampling to flow or other critical variations within the process under study.

The analytical program exemplified by the attached pages described that which is under way at a specific plant. Each mill study should be programed to carry out these analyses on the significant waste streams in accordance with parameters and frequencies listed. The locations at which the analyses are to be performed will determine the sample preservation method. It is recommended that all analyses be performed with minimum delay following collection.

SAMPLING AND ANALYSES PROGRAM

I. Identify Sampling Locations as Exemplified below:

Station #

1. Process Water - raw
2. Heavy Liquor - raw
3. Clarifier inflow - raw
6. Clarifier Effluent - primary

Sample stations 1, 2, 3, and 6 once/hr. Measure Temp., Measure/record flow.

9. Final Effluent

Sample this station once/hr, when flowing. Measure Temp. °C, when flowing. Measure/record flow, when flowing.

4. Ash Pond overflow

5. Color Pond overflow
7. Aeration Pond overflow
8. Stabilization Pond overflow
10. Non Process overflow
11. Raw Intake

Sample stations 4, 5, 7, 8, 10, and 11 once every 2 hrs. Measure/record Temp. Measure/record Flow, where measurable.

12. Clarifier Underflow

    Sample at the beginning and end of the underflow pumping operation.

13. Process Streams

    Sample as often as in-process changes warrant.

## II. SAMPLING INSTRUCTIONS

1. Fill sample collector completely; then pour out.
2. Fill again. Measure temperature immediately.
3. Stir rapidly; then pour off about 1 liter into sample bottle.
4. Mark (tag bottle) with Station #, time, flow, and temp.
5. Seal bottle, place in cooler, deliver to lab.
6. Keep sample in cooler until ready for compositing.
7. After returning from a sample run, enter the data collected on the log sheet.

## III. COMPOSITING INSTRUCTIONS

1. Arrange the hourly collections per sample station in the order of increasing flow rate.

2. Determine the volumetric ratio of each sample by dividing the lowest flow rate into each succeeding flow rate, i.e., flow rate 100 G/M, 110, 120, 150, 180, 200, etc. Divide 100 into each succeeding number to get ratios 1.1, 1.2, 1.5, 1.8, 2.0, etc.

3. Stir the sample well. Measure the amount to be removed, i.e., 500 Ml base x 1.2 = 600 Ml into a grad. cylinder. Transfer into the compositing bottle for the sample station.

4. Attach tag giving number of composites and volume of each as well as other pertinent data, i.e., station number, date, period of composite.

5. Mix well. Remove appropriate volume for shipment back to the main lab. The remainder will be used for analysis at the site.

## IV.. ANALYSES TO BE PERFORMED

| Location for Analysis | Test | STATION<br>1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13<br>A. | B. | C. | D. | etc. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | RAW | | | | | PRIMARY | | SECONDARY | | | | SOLIDS | | | | | |
| F | $BOD_5$ | D | D | D | D | D | D | D | D | D | D | D | — | D* | — | — | — | — |
| F | pH | D | D | D | D | D | D | D | D | D | D | D | D* | D* | — | — | — | — |
| F | Suspended Solids | D | D | D | D | D | D | D | D | D | D | D | D* | D* | — | — | — | — |
| F | V. SS. | D | D | D | D | D | D | D | D | D | D | D | D* | D* | — | — | — | — |
| F/L | Dissolved Solids | | D | | | | | | | D | O | | | D* | — | — | — | — |
| F/L | Ash | | D | | | | | | | D | O | | | | | | | |
| F | Color | | D | | | | D | D | D | D | O | O | | | | | | |
| L | Metals - (Fe. MN, Ni Cr, Pb, Hg, Cu, Zn) | | | | | | | | | T | | | | | | | | |
| L | Total N - (Kjeldahl + No2,No3) | | | | | | | | | T | T | | | | | | | |
| L | Total P. | | | | | | | | | T | T | | | | | | | |
| F/L | Sp. Cond. | D | | | | | | | | D | D | | | | | | | |

Key to Number Codes
1 - Process Sewer
2 - Heavy Liquor
3 - Clarifier in
4 - Ash Pond Out
5 - Color Pond out
6 - Clarifier out
7 - Aeration Pont out
8 - Stabilization Pond
9 - Final Effluent
10 - Non-Process Sewer
11 - Raw Water Intake
12 - Clarifier Underflow
13 - Process Stream A,B,C,D, etc refers to location within process

Key to Letter Codes
D - refers to daily composite
T - refers to total composite
O - refers to daily composite, run one time only
F - refers to Field analysis
L - refers to Home Laboratory analysis
D*- combine random grab samples if programmed sampling cannot be carried out.

## V. METHODS TO BE USED FOR MILLS SURVEYS

### Color. NCASI Method

1. Measure 200 ml sample and adjust pH to 7.6 by adding 1. N NaOH or 1. N $H_2SO_4$, while pH Meter is in sample.
2. Filter sample through 0.8 micron membrane.
3. Measure absorbance at 465 NM.
4. Read Color value from standard curve, prepared from pt. co. standard.

### Suspended Solids/Volatile Suspended Solids

Use 5.5cm fiberglass filter which has been heat treated and weighed prior to use.

### Metals Determinations

To preserve samples for metals analyses, add 5 ml reagent grade $HNO_3$ per liter of sample. Preserve at least 1 liter of each sample that is to have metals analyses. Also, save a 100 ml sample of the concentrated nitric acid used for preserving the metals samples. This will be used to establish a reagent blank for the metals.

### BOD5

1. Select the appropriate dilutions (no less than two) for the sample to be analysed.
2. Mix the composited sample well.
3. Transfer the appropriate volume with a pipette into a standard 300 ml BOD bottle.
4. Fill the BOD bottle into the neck with the dilution water; do not overflow. Allow air bubbles to escape.
5. Measure and record initial D.O. with Probe.
6. If any water is lost after probe is removed, add dilution water so that water level is into the neck of the BOD bottle.
7. Insert stopper carefully to avoid entrapment of air bubbles.

8. Place bottle in incubator at 20°C ± 1. Incubate 5 days ± 2 hours.

9. Measure and record final D. O. with Probe.

10. Make appropriate corrections for seed and dilution water as follows:

    a. Prepare 5% dilution of seed if aged primary or 50% dilution if raw river water, following steps 3 through 9 above.

    b. Calculate the D. O. equivalent of the seed plus dilution water and record.

11. Use those dilutions that fall within the D. O. depletion limits shown in Standard Methods p492.

12. Subtract the D. O. equivalent of the seed plus dilution water from the final D. O. of each sample.

13. Multiply the net D. O. depletion by the dilution factor to give the BOD value for the selected dilution.

14. a. If more than one dilution falls within the acceptable range, report the average of the BOD's of the individual samples.

    b. If all dilutions are depleted of D. O. report the highest dilution as greater than __.

    c. If all depletions are less than 2 mg/l D. O., report the lowest dilution only.

15. Run a glocuse-glutamic standard, preferably with each day's run of samples.

16. Run a duplicate dilution on approximately one-third of the samples daily.

BOD Dilution Water

1. Use distilled water only as base. Check for D. O.; aerate if necessary.

2. Check for copper with cuprethal reagent, or equivalent. This is necessary if the dilution water is purchased, or is from a source not previously checked for copper. Reject if Cu test is positive, i.e., greater than 0.01 mg/l.

3. Withdraw a volume of dilution water sufficient for the day's samples.
4. Add appropriate volumes of mineral and buffer solutions. (Standard Methods p489-491). Stir well.

5. a. Add 2 ml seed/liter if primary effluent from municipal STP is available.

   b. If not available use raw river water (50 ml/l).

6. Check pH. Should be 7.2.

B. Data Analysis and Transmittal

1. Upon completion of each Field Survey prepare a critical analysis of the verification program in which the following elements are considered.

   An analysis of the variability of results between the plant laboratory and the field study taking into account the split samples, standards duplicates, etc., and the results reported for each sample by the separate laboratories.

2. Based on your analysis, indicate the appropriate factors that need to be applied to the available historical data that will bring these into line with similar data being collected at other plants. Indicate how and where each factor should be applied.

3. Transmit the raw data which were obtained during the verification study including all analyses that were performed on all samples.

4. Transmit two copies of the 13 months of plant performance data which are to be used to establish the performance expectations of the treatment system being studied.

# APPENDIX V

## A. TENTATIVE PROCEDURE FOR COLOR MEASUREMENT OF PULPING WASTES AND THEIR RECEIVING WATERS - SPECTROPHOTOMETRIC METHOD.(2)

### (1) INTRODUCTION

The color of pulping waste or its receiving water is considered to be the color of the light transmitted by the waste solution after removing the suspended material, including the pseudocolloidal particles. It is recognized that the color characteristics of some wastes are affected by the light reflection from the suspended material in the wastes.

The term "color" is used herein to mean "true color"-that is, the color of the water from which the turbidity has been removed.

### (2) GENERAL DISCUSSION

(a) Principle: Color is determined by spectrophotometric comparison of the sample with known concentrations of colored solutions. The platinum-cobalt method of measuring color is given as the standard method, the unit of color being that produced by 1 mg/1 platinum, in the form of chloroplatinate ion. The ratio of cobalt to platinum may be varied to match the hue in special cases; the proportion given below is usually satisfactory to match the color of natural waters.

(b) Interference: Even a slight turbidity causes the measured color to be noticeably higher than the true color; therefore, it is necessary to remove turbidity before true color can be measured by spectrophotometric comparison. The recommended method for removal of turbidity is filtration through a membrane filter having a median porosity of 0.8 microns.

The color value of a water is highly pH dependent, and invariably increases as the pH of the water is raised. For this reason it is necessary, when reporting a color value, to adjust the pH of all samples to 7.6 with 1 N HCl or 1 N NaOH solution.

(c) Sampling: Samples for the color determination should be representative and must be taken in clean glassware. The color determination should be made within a reasonable period, as biologic changes occurring in storage may affect the color and alter the pH value.

### (3) APPARATUS

(a) Spectrophotometer, having absorption cells of the following length for minimum detectable color,

| Absorption cell | Minimum Detectable |
|---|---|
| 30 | 1 |
| 20 | 5 |
| 10 | 8 |
| 5 | 10 |
| 1 | 25 |

a narrow (10 mu or less) spectral bank and an effective operating range from 400 to 700 mu.

(b) pH meter, for determining the sample pH.

(c) Filtration system, consisting of flask, vacuum source, filter holder, and 0.8 micron porosity membrane filters.

## (4) PREPARATION OF STANDARDS

If a reliable potassium chloroplatinate standard solution cannot be purchased from a laboratory supply house, it may be replaced by chloroplatinic acid, which which the analyst can prepare from metallic platinum. Commercial chloroplatinic acid should not be used because it is very hygroscopic and therefore may vary in platinum content. Potassium chloroplatinate is not hygroscopic.

Dissolve 1.246 g potassium chloroplatinate, K2PtC16 (equivalent to 0.500 g metallic platinum) and 1 g crystallized cobaltous chloride, CoC12.6H2O (equivalent to about 0.25 g metallic cobalt) in distilled water with 100 ml concentrated HC1 and dilute to 1 liter with distilled water. This stock standard has a color of 500 units.

If potassium chloroplatinate is not available, dissolve 0.500 g pure metallic platinum in aqua regia with the aid of heat; remove nitric acid by repeated evaporation with fresh portions of concentrated HCl. Dissolve this product together with 1 g crystallized cobaltous chloride as directed above.

Prepare standards having colors of 25, 50, 100, 150, 200, and 250 by diluting 2.5, 5.0, 10.0, 15.0, 20.0, and 25.0 ml stock color standard with distilled water to 50 ml in stoppered volumetric flasks. Protect these standards against evaporation and contamination when not in use.

Transfer a suitable portion of each final solution to a 10 mm absorption cell from a "matched set" of cells and measure the absorbance at 465 mu. As reference use distilled water for instrument calibration to zero absorbance.

Construct a calibration curve by plotting absorbance values against color units similar to the sample curve presented in Appendix V Figure 8.

Appropriately lower color standards should be used for the calibration curve with longer absorption cells. For example, employing the 10 to 20 centimeter cells, use standards of 5, 10, 15, 20, 25, 50, 75 and 100 units of color, and develop the curve similar to the appropriate cell length illustrated by the set of curves presented in Figure 6 of the report.

### (5) PROCEDURE

Preparation of sample: Select a 200 ml sample of waste or water, adjust pH to 7.6 with HCl or NaOH as indicated in Section 2 (2). If the overall volume change is greater than one per cent, discard sample and start anew with stronger solutions of HCl or NaOH for the pH adjustment. In any event, the volume change in the final sample should be no more than one per cent.

Take a 50 ml aliquot of the pH adjusted sample and filter through a 0.8 micron porosity membrane filter pre-rinsed with distilled water. Then transfer an appropriate portion of the filtered sample to a 10 mm absorption cell and measure its absorbance at 465 mu, using distilled water for the blank.

If the sample contains very high concentrations of turbidity (200 to 1000 J.T.U.) successively smaller aliquots of the sample should be used per membrane filter. This possibility may requie filtration of 2 or 3 aliquots to accumulate sufficient sample to fill the appropriate absorption cell. The guideline to follow in selection of aliquot volume to filter should be based on the visual appearance of a sudden rapid reduction in filtration rate through the filter. This phenomenon would indicate the beginning of filter plugging, and that possible loss of color would result on further filtration of the sample. Filtration should be stopped immediately on this occurrence, and the filter replaced with a clean prerinsed filter. Prerinsing of the filter with distilled water is recommended to prevent any change in pH resulting from use of "acid washed" filters.

Calculate the color units in the sample by comparing the absorbance reading with a standard curve secured by carrying out the procedure indicated in Section 4 (2).

Report the color results in whole numbers and record as follows:

| Color Units | Record to Nearest |
|---|---|
| 1-100 | 1 |
| 101-500 | 5 |

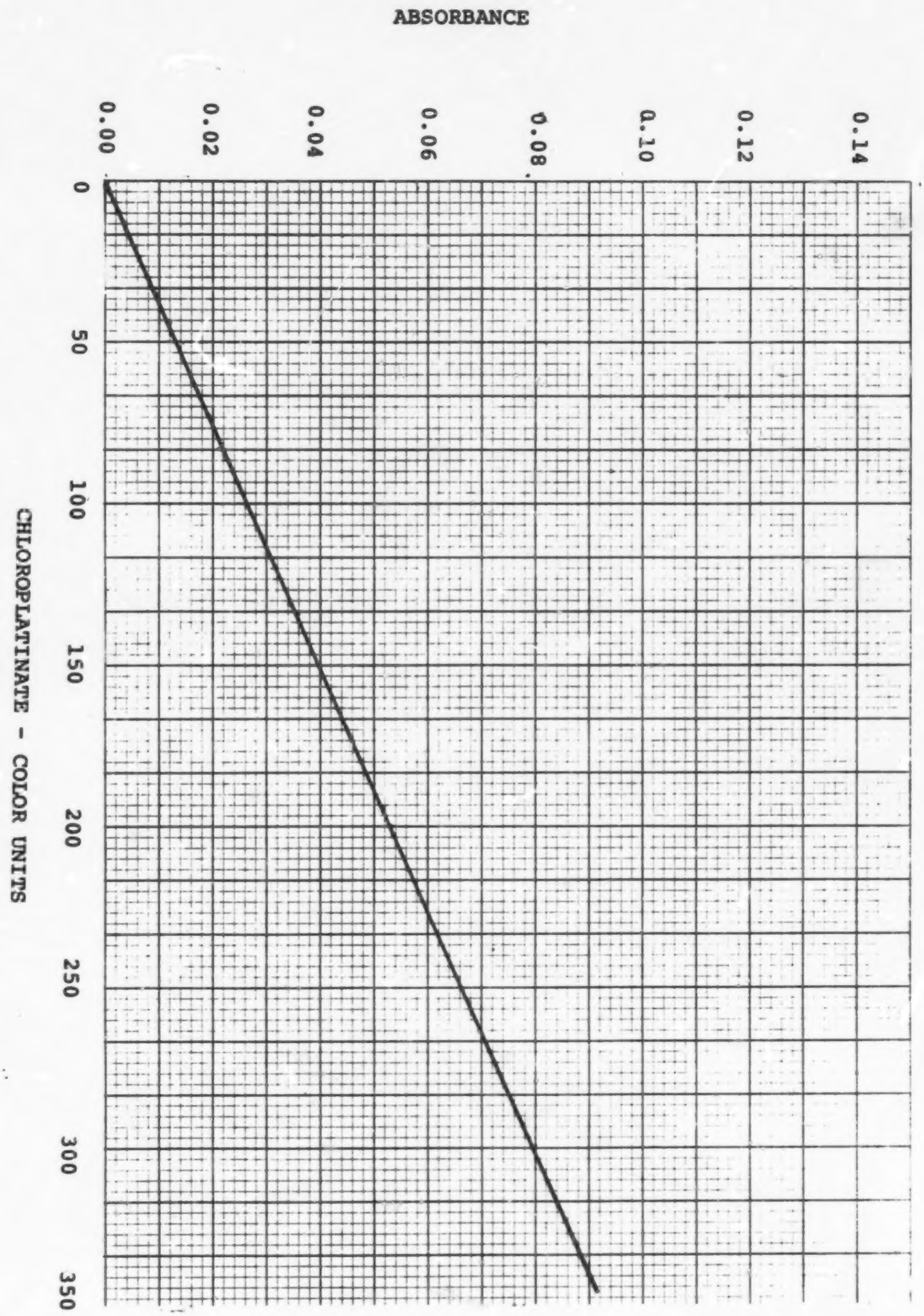

FIGURE 8 TYPICAL CALIBRATION CURVE

## APPENDIX VI

## Abbreviations

| | |
|---|---|
| A | Aeration |
| AA | Annual Average |
| AB | Alternating Basins |
| An.Av. | Annual Average |
| APHA CU | American Public Health Association Color Unit |
| API | American Paper Institute |
| AS | Activated Sludge |
| ASB | Aerated Stabilization Basin |
| BATEA | Best Available Technology Economically Achievable |
| BPCTCA | Best Practicable Control Technology Currently Available |
| C | Clarifier |
| CD | Controlled Discharge |
| COD | Chemical Oxygen Demand |
| CU | Color Unit |
| DAF | Dissolved Air Flotation |
| g | grams |
| gal/ton | Gallons per short ton |
| gpd | Gallons per day |
| gpd/sq.ft. | Gallons per day per square foot |
| gpm | Gallons per minute |
| hp | Horsepower |
| kiloliters/kkg | 1000 Liters per metric ton |
| kkg | 1000 Kilograms (one metric ton) |

| | |
|---|---|
| kg/kkg | Kilograms per 1000 kilograms<br>kilograms per metric ton |
| KWH | Kilowatt Hours |
| MGD, mgd | Million gallons per day |
| MLD | Million liters per day |
| MM | Maximum Month |
| Na | Sodium |
| NCASI | National Council for Air and Stream Improvement, Inc. |
| NH3 | Ammonia |
| NPDES | National Pollutant Discharge Elimination System |
| NSM | Non-Standard Methods |
| NSPS | New Source Performance Standards |
| NPDES | Refuse Act Permit Program |
| SM | Standard Methods |
| SO | Storage Oxidation Pond |
| SS | Suspended Solids (same as TSS) |
| SS | Secondary Settling |
| TF | Trickling Filter |
| ton | Short ton (2000 pounds) |
| tons/day | Short tons per day |
| TSS | Total Suspended Solids (same as SS) |

# APPENDIX VII

## METRIC UNITS

## CONVERSION TABLE

| MULTIPLY (ENGLISH UNITS) | | by | TO OBTAIN (METRIC UNITS) | |
|---|---|---|---|---|
| ENGLISH UNIT | ABBREVIATION | CONVERSION | ABBREVIATION | METRIC UNIT |
| acre | ac | 0.405 | ha | hectares |
| acre - feet | ac ft | 1233.5 | cu m | cubic meters |
| British Thermal Unit | BTU | 0.252 | kg cal | kilogram - calories |
| British Thermal Unit/pound | BTU/lb | 0.555 | kg cal/kg | kilogram calories/kilogram |
| cubic feet/minute | cfm | 0.028 | cu m/min | cubic meters/minute |
| cubic feet/second | cfs | 1.7 | cu m/min | cubic meters/minute |
| cubic feet | cu ft | 0.028 | cu m | cubic meters |
| cubic feet | cu ft | 28.32 | l | liters |
| cubic inches | cu in | 16.39 | cu cm | cubic centimeters |
| degree Fahrenheit | F° | 0.555(°F-32)* | °C | degree Centigrade |
| feet | ft | 0.3048 | m | meters |
| gallon | gal | 3.785 | l | liters |
| gallon/minute | gpm | 0.0631 | l/sec | liters/second |
| horsepower | hp | 0.7457 | kw | killowatts |
| inches | in | 2.54 | cm | centimeters |
| inches of mercury | in Hg | 0.03342 | atm | atmospheres |
| pounds | lb | 0.454 | kg | kilograms |
| million gallons/day | mgd | 3,785 | cu m/day | cubic meters/day |
| mile | mi | 1.609 | km | kilometer |
| pound/square inch (gauge) | psig | (0.06805 psig +1)* | atm | atmospheres (absolute) |
| square feet | sq ft | 0.0929 | sq m | square meters |
| square inches | sq in | 6.452 | sq cm | square centimeters |
| tons (short) | t | 0.907 | kkg | metric tons (1000 kilograms) |
| yard | y | 0.9144 | m | meters |

* Actual conversion, not a multiplier

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